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Office of Radiation Programs

INTERNATIONAL NUMERICAL MULTIPLE AND SUBMULTIPLE PREFIXES

Multiples and submultiples	Prefixes	Symbols	Pronunciations
10^{12}	tera	T	tĕr'a
10^{9}	giga	G	ji'ga
10^{6}	mega	M	mĕg'a
10^{3}	kilo	k	kil'o
10^{2}	hecto	h	hĕk'to
10	deka	da	dĕk'a
10^{-1}	deci	d	dĕs'i
10^{-2}	centi	c	sĕn'ti
10^{-3}	milli	m	mil'i
10^{-6}	micro	μ	mi'kro
10^{-9}	nano	n	nan'o
10^{-12}	pico	p	pe'ko
10^{-15}	femto	f	fĕm'to
10^{-18}	atto	a	at'to

SYMBOLS, UNITS, AND EQUIVALENTS

Symbol	Unit	Equivalent
Å	angstrom	10^{-10} meter
a	annum, year	
BeV	billion electron volts	GeV
Ci	curie	3.7×10^{10} dps
cm	centimeter(s)	0.394 inch
cpm	counts per minute	
dpm	disintegrations per minute	
dps	disintegrations per second	
eV	electron volt	1.6×10^{-12} ergs
g	gram(s)	
GeV	giga electron volts	1.6×10^{-3} ergs
kg	kilogram(s)	1,000 g = 2.205 lb.
km^2	square kilometer(s)	
kVp	kilovolt peak	
m^3	cubic meter(s)	
mA	milliampere(s)	
mCi/mi^2	millicuries per square mile	0.386 nCi/m^2 (mCi/km^2)
MeV	million (mega) electron volts	1.6×10^{-5} ergs
mg	milligram(s)	
mi^2	square mile(s)	
ml	milliliter(s)	
mm	millimeter(s)	
nCi/m^2	nanocuries per square meter	2.59 mCi/mi^2
pCi	picocurie(s)	10^{-12} curie = 2.22 dpm
R	roentgen	
rad	unit of absorbed radiation dose	100 ergs/g

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RADIOLOGICAL HEALTH DATA AND REPORTS

Volume 12, Number 12, December 1971

Radiological Health Data and Reports, a monthly publication of the Environmental Protection Agency, presents data and reports provided by Federal, State, and foreign governmental agencies, and other cooperating organizations. Pertinent original data and interpretive manuscripts are invited from investigators.

In August 1959, the President directed the Secretary of Health, Education, and Welfare to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels. This responsibility was delegated to the Bureau of Radiological Health, Public Health Service. Pursuant to the Reorganization Plan No. 3 of 1970, effective December 2, 1970, this responsibility was transferred to the Radiation Office of the Environmental Protection Agency which was established by this reorganization.

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ENVIRONMENTAL PROTECTION AGENCY

William D. Ruckelshaus, Administrator

Reports

Impact of Tritium on the Watch Industry, 1966–1970

F. J. Bradley, R. Blais and A. Jones[1]

Tritium contamination from self-luminous watches at wholesale importers, retailers, and refinishers has been investigated. Air, surface-wipe, and urine samples were analyzed for tritium content by liquid scintillation counting to determine the extent of the contamination.

Eleven storage vaults were surveyed, and the highest human exposure (0.5 rem per year) was found in a firm which handled approximately 200 Ci/a and had poor vault ventilation. Contamination was negligible in vaults at retail establishments.

The casing and repair areas of a firm which handled more than 100 Ci/a had air, surface, and human contamination values of 0.063 pCi/cm^3, 11,200 pCi/100 cm^3, 0.48 μCi/liter, and 0.039 pCi/cm^3, 7,820 pCi/100 cm^2, and 0.22 μCi/liter, respectively, on a yearly average. The casing and repair areas of a firm which handled about 10 Ci/a had air, surface, and human contamination values of background, 430 pCi/100 cm^2 and 0.08 μCi/liter, and background, 807 pCi/100 cm^2, and 0.05 μCi/liter, respectively, on a yearly average.

A refinisher who handled an estimated 30-50 Ci/a had air, surface, and human contamination values of background, 33,600 pCi/100 cm^2 (near stripping solution), and background, respectively, on a yearly average.

In the New York Metropolitan Area there are about 40 firms manufacturing, importing, and distributing self-luminous watches containing tritium. In plants belonging to these firms there are various areas where employee exposure to tritium may exist. Specifically, in a manufacturing plant, exposure areas include areas for mixing the tritiated compound with phosphor and adhesive (usually the phosphor is mixed with tritium in one plant and the adhesive is added to the mixture in a different plant at the time the paint is to be applied) and areas for painting watch hands and dials. Based on studies by others (*1-2*) and our own experience, there is no doubt that at the manufacturing stage, significant employee exposures can occur.

Less well known are the exposures to employees in other steps of the self-luminous watch industrial cycle (figure 1). For reasons of commerce, components of watches are imported into the United States primarily in the New York City area and assembled or cased into complete watches. The watches are then stored and distributed later to retailers throughout the country. Occasionally, at the consumer level, watches are returned for repair. At the end of the cycle some watches are returned to firms that specialize in refinishing the watch dials and hands according to customer specifications. Self-luminous watches at the present time may contain radium, tritium, or promethium-147 when they are returned, but they are usually repainted with radium.

All firms handling more than 2,000 self-luminous watches (representing about 2-10 Ci of tritium) at any one time are required to possess a radioactive materials license for possession and use of tritium.

This report covers studies that were conducted in watch storage, casing, repair, and refinishing areas. The survey techniques used in these areas were designed to determine the tritium surface and air contamination and human exposures. Surface contamination was determined by wiping an area of approximately 100 cm^2 with a Whatman No. 42 filter

[1] New York State Department of Labor, Division of Industrial Hygiene, 80 Centre Street, New York, N.Y. 10013.

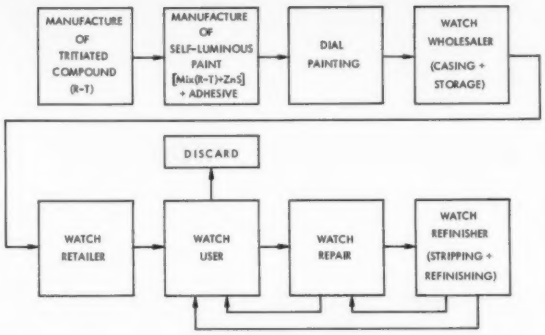

Figure 1. Industrial cycle for a self-luminous watch

paper (approximate area 6.2 cm²). Particulate and tritiated water vapor contamination was determined by drawing air, first through a filter paper, and then through two midget impingers containing 10 ml of water each. Human tritium exposure was determined by collecting urine samples from employees. All samples were analyzed for their tritium content using the standard liquid scintillation counting technique (*3*).

Watch storage areas

In the first phase of the study, the storage vaults of 11 firms were checked three times in an 11-month period. Table 1 summarizes the results from the checks; the first nine listed firms are wholesale-importers, the last two are retailers. Firm X handled approximately 40,000 watches annually which represents about 200 Ci of tritium. The average surface contamina-

Table 1. Results of storage area survey

Firm	Date	Number of self-luminous watches on hand	Tritium activity on hand (Ci)	Number of self-luminous watches handled yearly	Surface activity $\left(\frac{pCi}{100\ cm^2}\right)$	Air concentration [a] $\left(\frac{pCi}{cm^3}\right)$	Resuspension factor [b] ($\times 10^{-2}$ cm^{-1})	Room ventilation [c]
X	Oct 1966	15,000	84	40,000	576	2.13	37	
	Jan 1967				2,076	2.05	9.85	
	Aug 1967	10,000	56		594	.621	10.4	Poor
I	Oct 1966	30,000	30		3,308	.066	.20	
	Jan 1967				3,825	.110	.28	
	Aug 1967	30,000	30		291	.138	4.7	Good
IV	Oct 1966	2,000	5	40,000	381	.097	2.54	
	Jan 1967				904	.194	2.14	
	Aug 1967	10,000	25		198	.512	26	Poor
IX	Oct 1966	2,000	6	6,500	462	.140	3.0	
	Jan 1967				557	.367	6.6	
	Aug 1967	1,500	4.5		850	.122	1.44	None
VIII	Oct 1966	5,315	2.7		<1.73	Background		
	Jan 1967				12.8	.0439	34.4	
	Aug 1967	4,400	2.2		<2.06	.0436	>212	Poor
II	Oct 1966	2,850	2.0		356	.077	2.16	
	Jan 1967				574	.168	2.93	
	Aug 1967	2,850	2.0		201	.310	15.5	Good
III	Oct 1966	600	.48		2,764	Background		
	Jan 1967				2,730	.179	.656	
	Aug 1967	1,500	1.2		696	.150	2.16	Good
VI	Oct 1966	100	.03	4,000	6.0	Background		
	Jan 1967	3,000	.96		38.3	Background		
	Aug 1967	500	.16		6.7	Background		Good
XI	Oct 1966	50	.25	300	152	.093	6.1	
	Jan 1967				84.0	.133	15.8	
	Aug 1967	300	1.5		48.8	.156	32.1	None
VII	Oct 1966	2,000			4.6	.031	67	
	Jan 1967	0			5.9	Background		
	Aug 1967							None
V	Oct 1966	100			9.1	Background		None
	Jan 1967				4.2	.0340	80	
	Aug 1967	100			<2.06	.0356	>173	(open area)

[a] Air concentration classified as background unless it is equal to or greater than the background plus 3σ value for the Tri-Carb counter (outside the 99.9 percent confidence band around counter background).

[b] Resuspension factor = $\frac{\text{air concentration in pCi/cm}^3}{\text{surface concentration in pCi/cm}^2}$.

[c] None–no mechanical ventilation provided. Poor–mechanical ventilation provided, but air flow across vault entrance less than 10 linear feet per minute. Good–mechanical ventilation provided, and air flow across vault entrance greater than 10 linear feet per minute.

tion varied from 576 pCi/100 cm^2 to 2,076 pCi/100 cm^2. The air concentration for the October 1966 survey was 2.13 pCi/cm^3 and for the January 1967 survey, 2.05 pCi/cm^3, which were the highest air concentrations observed during the study. In August 1967, the air concentration was 0.62 pCi/cm^3 and the number of watches in storage was down from 15,000 in October 1966 to 10,000. The total tritium activity on hand at the time of the survey ranged from 84 Ci in October 1966 to 56 Ci in August 1967. Initially, a survey was conducted during the summer months because greater air and surface contamination was thought probable due to the generally high humidity at that time of year. The vault ventilation was rated as poor in this firm.

Firm I had on hand 30,000 watches or 30 Ci of tritium during the October 1966 and August 1967 surveys, but the firm did not know precisely how many self-luminous watches were handled on an annual basis. The average surface activity in the vault ranged from 291 pCi/100 cm^2 to 3,825 pCi/100 cm^2 and the air concentration ranged from 0.066 to 0.138 pCi/cm^3, considerably lower than Firm X. The ventilation in this vault was rated good and certainly contributed to the lower air concentration in addition to the lower total activity on hand at the time of the survey as compared to Firm X. The remaining nine storage areas which were surveyed handled less activity and had less surface activity, although Firm III, reporting only 600 watches (representing a total activity of 0.5 Ci of tritium) on hand during the October 1966 survey, had an average surface activity of 2,764 pCi/100 cm^2 at that time. The air concentration for this firm varied from background in October to 0.179 pCi/cm^3 in January 1967.

Urine samples were obtained from persons working in the vaults at several firms, and based on average tritium excretion values, estimated annual dose equivalents were calculated. Table 2 summarizes these dose estimates.

In all cases, the firms handling less than 2,000 watches had air concentrations less than 0.5 pCi/cm^3, which is the International Commission on Radiation Protection's (ICRP) recommended value for an uncontrolled area, and

Table 2. Annual dose equivalent estimated for persons working in storage areas

Firm	Survey period 1967	Excretion rate $\left(\frac{\mu Ci}{liter}\right)$	q[a] (μCi)	D^a $\left(\frac{mrem}{week}\right)$	D (mrem/a)
X	January	[b] 4.39	[b] 157	[b] 15.7	
	August	.995	35.5	3.55	
				[c] 9.7	500
I	August	.806	28.8	2.88	[d]
IV	January	.184	6.57	.657	
	August	.463	16.5	1.65	
				[c] 1.16	60
III	January	.189	6.75	.675	
	August	.161	5.75	.575	
				[c] .625	33
XI	January	[b] .0865	[b] 3.09	[b] 3.09	
	August	.244	8.7	.870	
				[c] .59	31

[a] Assumes 28 μCi/liter is equivalent to q = 1,000 μCi and D = 100 mrem/week.
[b] Average of two persons.
[c] Average.
[d] No estimate made due to insufficient data.

surface contamination values ranged from 4 to 2,800 pCi/100 cm^2. Resuspension factors in units of pCi/cm^3 per pCi/cm^2 ranged from 2×10^{-3} cm^{-1} to >2 cm^{-1}. As one might expect these values are considerably higher than those found with nonvolatile plutonium compounds reported by Jones and Pond (*4*). Resuspension factors in that study ranged from 2×10^{-10} to 5×10^{-7} cm^{-1}.

As with many real life studies of this type there was observed in the variables studied a considerable range and general lack of correlation among the variables. Specifically, as table 1 indicates, there is no consistent correlation between tritium air and surface contaminations. But if one combines the total tritium activity on hand, the vault ventilation and the ability of tritium to exchange with stable hydrogen, especially in the water molecule, some of the apparent discrepancies are at least plausible.

Watch casing, repair, and refinishing areas

Table 3 gives the average tritium surface contamination observed in various areas in a sample of 21 firms which were inspected over a period of 1 year. Average surface contamination values ranged from 41 to 54,200 pCi/100 cm^2 with the greatest contamination generally observed in the casing area. The nature of the workload in the various areas in the watch firms with a mix of non-self-luminous and self-luminous watches makes it extremely difficult

Table 3. Results of surface wipe survey

Firm	Average surface activity $\left(\frac{pCi}{100\ cm^2}\right)$			
	Casing area	Repair area	Packing area	Quality control area
19	54,200			
	7,020			
	2,380			
13	9,760	2,690		
	2,820	160		
9	9,210	6,430		922
14	5,820			
6	4,660			
2	2,010			
15	1,740	5,390		
3	1,560			
11	1,480			
12	1,400			
8	1,100	363		
21	720		45	
1	639	4,000		
17	628			
4	591		1,030	
10	451			
7	413	843		
20	301			
5	296			
18	85			
16	41			

and impractical to segregate work areas in the radiation sense into controlled and uncontrolled areas. Therefore, surface contamination guidelines for uncontrolled areas must be met.

Based, at least partially, on the results of the watch storage area phase of the study, a guideline for tritium surface contamination in uncontrolled areas was established at 1,000 pCi/100 cm² average and 5,000 pCi/100 cm² maximum.

One notices from table 3 that two repeat visits were required to get Firm 19 down to 2,000 pCi/100 cm² average which was still a factor of two above the guideline.

While the tritium surface contamination guideline is 10 times the guideline in use by the New York State Department of Labor for all other beta-gamma emitters, there were still 13 firms (62 percent) above the guidelines. Tritium decontamination is a problem with some cleaned areas ending up with higher surface activity than before the cleaning. In addition, due to tritium's low radiotoxicity, it is possible that the guidelines may be set too low.

The next phase in the study was conducted in three firms over a 12-month period in an effort to correlate the surface, air, and urine excretion values. No special attempt was made to change handling procedures during this phase of the study but firms had removed the green felt pads, which are the hallmark of a watchmaker, from the workbenches because the pad was an obvious source of tritium accumulation.

Watch casing and repair areas

Two watch importers, designated Firm A and Firm B, were surveyed monthly over a 1 year period. In each firm, the casing and repair areas were checked.

In the casing area of Firm A, 15 persons were employed to perform two operations. One operation involved the insertion of a watch movement into a watch case; 100 watches were cased per man per day. The other operation in the same area involved the repair of new watches; 20–25 watches were handled per man per day. Approximately 23 percent of the watch line handled by Firm A is self-luminous and 142 curies were handled per year in the casing area during 1969. Each individual work area was cleaned daily with a sponge. The average surface activity for the 12-month period was 11,200 pCi/100 cm². The survey results are summarized in table 4 and plotted in figure 2 on a semi-logarithmic scale. The log scale was necessary due to the extremes in the activity found. In figure 2, the floor and table surface activities are plotted separately with the table showing the highest activity. This is not surprising since hot spots, presumably arising from specks of self-luminous material flaking off the watches, are to be expected. The average air concentration during the same period was 0.058 pCi/cm³, which is 11.6 percent of the maximum permissible air concentration for uncontrolled areas. Urine samples were collected from two persons, and analysis of the samples yielded an average value of 0.48 μCi/liter, which is 17.3 percent of the permitted value for persons working in uncontrolled areas. Resuspension factors ranged from 3.3×10^{-4} to 2.0×10^{-3} cm⁻¹, a factor of 10-1,000 lower than was observed in the storage area.

In the repair area for used watches, 43 watchmakers were employed. It was estimated that a total of 137 curies of tritium activity was handled per year. The individual work

Table 4. Survey results of casing area, Firm A

Time	Average surface activity ($\frac{pCi}{100\ cm^2}$)	Air concentration ($\frac{pCi}{cm^3}$)	Resuspension factors (cm^{-1})	Excretion value ($\frac{\mu Ci}{liter}$)
May 1969	5,380	0.087	1.62×10^{-3}	0.51
June 1969	8,170	.108	1.32×10^{-3}	.47
July 1969	4,770	.097	2.03×10^{-3}	.28
August 1969	20,900	.091	4.35×10^{-4}	.44
September 1969	3,420	[a] .037	—	.52
October 1969	1,720	[a] .030	—	.60
November 1969	17,700	[a] .010	—	.64
December 1969	11,400	.103	9.03×10^{-4}	.47
January 1970	18,400	.060	3.26×10^{-4}	.47
February 1970	26,400	[a] .005	—	.47
March-April 1970	4,880	[a] .006	—	.45
Average	11,200	.058	—	.48
Percent of maximum permissible concentration	[b] 11.2	11.6		17.3

[a] Within background plus 3σ.
[b] See text, page 608, for explanation.

Table 5. Survey results of repair area, Firm A

Time	Average surface activity ($\frac{pCi}{100\ cm^2}$)	Air concentration ($\frac{pCi}{cm^3}$)	Resuspension factors (cm^{-1})	Excretion value ($\frac{\mu Ci}{liter}$)
May 1969	3,500	0.062	1.76×10^{-3}	0.30
June 1969	15,100	.059	3.9×10^{-4}	.28
July 1969	2,660	.078	2.93×10^{-3}	.19
August 1969	4,260	.055	1.29×10^{-3}	.22
September 1969	26,900	[a] .011	—	.26
October 1969	902	[a] .025	—	.19
November 1969	3,560	[a] .009	—	.22
December 1969	1,370	.083	6.08×10^{-3}	.19
January 1970	8,940	[a] .024	—	.21
February 1970	16,000	.011	—	.16
March-April 1970	2,860	[a] .014	—	.23
Average	7,820	.039		.22
Percent of maximum permissible concentration	[b] 7.8	7.8		7.9

[a] Within background plus 3σ.
[b] See text, page 608, for explanation.

benches were cleaned, in most cases daily, and there was a general weekly cleanup with disinfectant. The annual average surface activity was 7,820 pCi/100 cm² and the monthly values are summarized in table 5. The surface activity

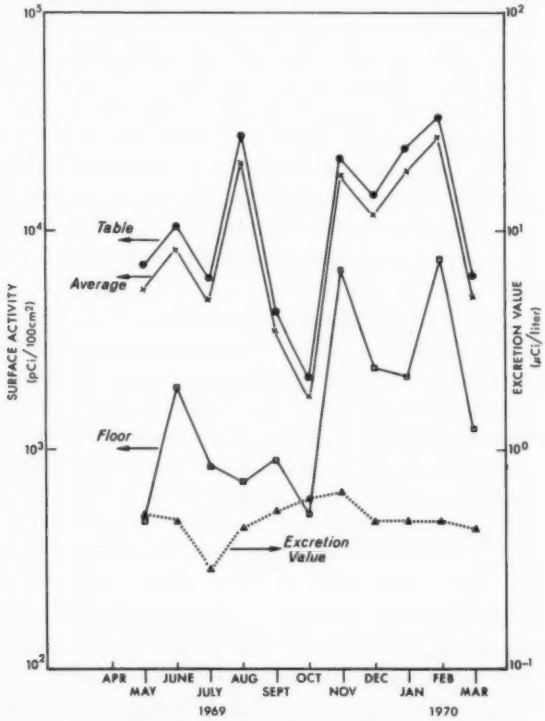

Figure 2. Casing area, Firm A

results are plotted in figure 3. The month-to-month variation was less on the floor compared with the activity noted on the tables. The least variation was found in the average urine excretion value, which is 0.22 μCi/liter for the survey period. Since the body acts to integrate and smooth out the exposure, the smaller variations are to be expected. The average air concentration was 0.039 pCi/cm³, slightly above background and 7.8 percent of the maximum recommended value. Resuspension factors ranged from 3.9×10^{-4} to 6.1×10^{-3} cm⁻¹.

Firm B employed a varying number of people in the casing area. The number of people employed ranged from a high of 18 during the May through December 1969 period to a low of 12 in the slack period from January through March 1970. The total activity of tritium handled was approximately 10.5 curies per year. Between 5 to 10 percent of the watches contained tritium. Workbenches were washed weekly and floors cleaned once per month. The average surface activity over the 12-month period was 430 pCi/100 cm² and the average excretion value for 2 persons was 0.08 μCi/liter. The monthly results are given in table 6 and plotted in figure 4. The air concentration was at background. When they could be calculated, resuspension factors varied from 6.7×10^{-3} cm⁻¹ to 4.9×10^{-2} cm⁻¹.

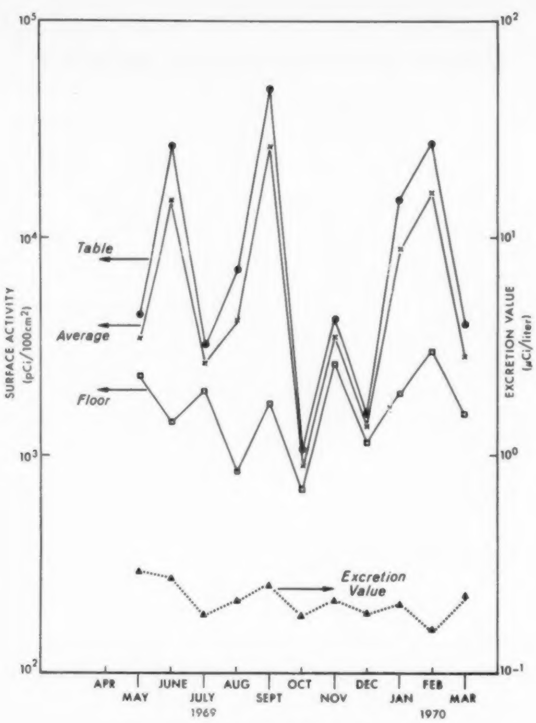

Figure 3. Repair area, Firm A

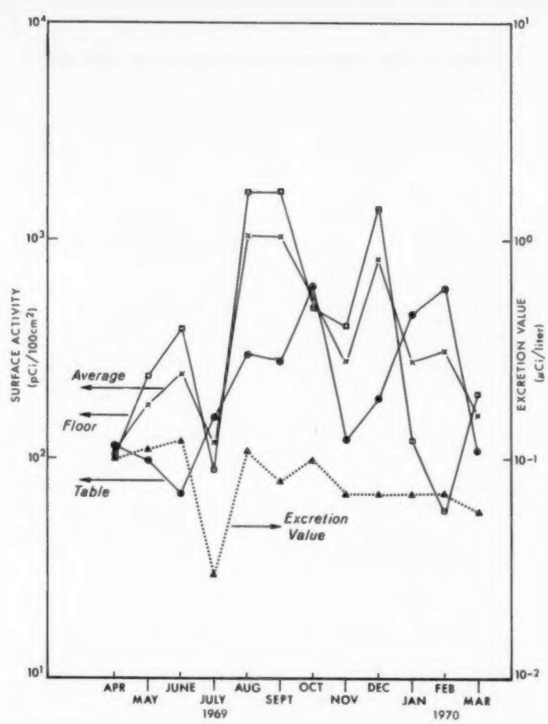

Figure 4. Casing area, Firm B

In the repair area, employment during the study period varied between a minimum of 17 to a maximum of 25 watchmakers. The total tritium activity handled in this area was estimated to be about 7.5 curies per year. Benches were cleaned twice per week and floors once per month. The average surface activity was 807 pCi/100 cm² and the average excretion value over the 12-month period was 0.05 μCi/liter which is 1.8 percent of the maximum permissible value. The monthly values are given in table 7 and plotted in figure 5. The air concentration was background in all but the month of December 1969. A resuspension factor of 1.6×10^{-2} cm^{-1} was calculated for the December 1969 visit.

The great difference in surface activity between Firms A and B can be attributed to the amount of tritium handled per year. Firm A, which handled more than 10 times the activity handled by Firm B per year, had an average surface activity more than 10 times the average surface activity of Firm B.

Table 6. Survey results of casing area, Firm B

Time	Average surface activity $\left(\frac{pCi}{100\ cm^2}\right)$	Air concentration $\left(\frac{pCi}{cm^3}\right)$	Resuspension factors (cm^{-1})	Excretion value $\left(\frac{\mu Ci}{liter}\right)$
April 1969	110	0.042	3.82×10^{-2}	0.10
May 1969	174	[a] .027	—	.11
June 1969	243	[a] .001	—	.12
July 1969	120	.059	4.92×10^{-2}	.03
August 1969	1,050	[a] .026	—	.11
September 1969	1,030	[a] .006	—	.08
October 1969	557	[a] .002	—	.10
November 1969	279	.002	—	.07
December 1969	841	.056	6.66×10^{-3}	.07
January 1970	283	[a] .027	—	.07
February 1970	319	[a] .014	—	.07
March 1970	159	[a] .004	—	.06
Average	430	Background		0.08
Percent of maximum permissible concentration	[b] 0.4			2.9

[a] Within background plus 3σ.
[b] See text, page 608, for explanation.

Watch refinishers

At the end of the watch cycle there exist firms which strip off the paint on the watch dial and hands and redecorate them according to customers' specifications. The dials and hands

Table 7. Survey results of repair area, Firm B

Time	Average surface activity ($\frac{pCi}{100\ cm^2}$)	Air concentration ($\frac{pCi}{cm^3}$)	Resuspension factors (cm^{-1})	Excretion value ($\frac{\mu Ci}{liter}$)
April 1969	647	[a] 0.004	—	0.04
May 1969	354	[a] .010	—	.06
June 1969	4,390	[a] .021	—	.02
July 1969	362	[a] .010	—	.03
August 1969	312	[a] .008	—	.04
September 1969	799	[a] 0	—	.05
October 1969	396	[a] .01	—	.04
November 1969	316	[a] .006	—	.06
December 1969	356	.056	1.57×10^{-2}	.09
January 1970	429	[a] .022	—	.04
February 1970	600	[a] .012	—	.07
March 1970	724	[a] .011	—	.06
Average	807	Background		.05
Percent of maximum permissible concentration	[b] 0.8			1.8

[a] Within background plus 3σ.
[b] See text, page 608, for explanation.

are placed in a small tray of paint remover whose composition varies among firms. It is a lye solution in one firm, acetone in another firm, and, at the firm studied on a monthly basis, a paint solvent solution. After a soaking period, the dials and hands are removed, dried and refinished. The paint removal operation is called stripping. In the firm studied (Firm C) seven employees came in contact with the dials and hands up to and including the stripping operation. A crude estimate gave a value of 30-50 curies of tritium handled per year.

The surface activity averaged 33,600 pCi/100 cm^2 for the room in which the stripping was done. This value is biased and does not truly represent the room average since the number of smears taken was small and concentrated around the stripping solution. Because this room had an approximate volume of 2.3×10^8 cm^3 (8,000 ft^3) the air concentration was background in most months except in two instances when high filter paper particulate activity was noted but little activity was found in the impingers. The urine excretion value was also near background for the person doing the stripping. Other areas in the plant, such as the refinishing room and machine shop, had negligible average surface activity.

Despite some hot spots, as indicated by the high smear values, the level of radiation from self-luminous tritium watches now being refinished does not represent any hazard to the worker at this time.

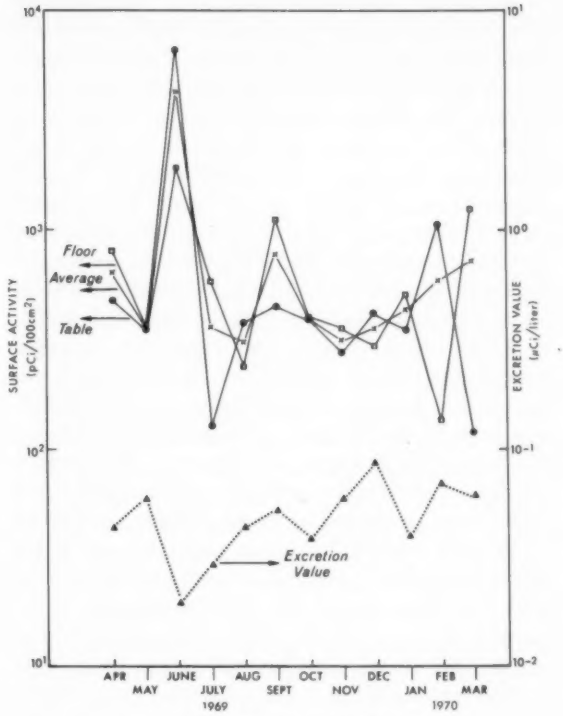

Figure 5. Repair area, Firm B

Removable surface contamination guidelines for uncontrolled (inactive) areas

The dilemma and pitfalls posed by setting surface contamination guidelines are well illustrated by this study. In the storage area survey, high tritium air concentration values were observed relative to the surface contamination values. This resulted in high resuspension values which ranged from 2×10^{-3} cm^{-1} to >2 cm^{-1}, while in the casing and repair areas relatively high surface contamination values did not lead to high air or human contamination values. The resuspension values were also lower, ranging from 3.3×10^{-4} cm^{-1} to 4.9×10^{-2} cm^{-1}. Therefore, the surface contamination guideline of 1,000 pCi/100 cm^2 average and 5,000 pCi/100 cm^2 maximum, which was established partly on the basis of the storage area survey, was quite adequate in the casing and repair areas.

While other investigators (*5-6*) have detailed the problems associated with defining and setting surface contamination limits, most of their remarks and investigations involved controlled areas. Our efforts were directed towards guidelines that would be applicable to uncontrolled areas or "inactive" areas. Dunster (*7*) has attempted to establish along more or less empirical lines surface contamination guidelines for both controlled and uncontrolled areas. He came to the conclusion that the limiting factor was dose to the skin from deposited radionuclides. But to date, no generally accepted model has arisen similar to the air and water exposure models. Consequently, several different sets of limits have been published and are summarized in table 8. One can construct a model wherein the activity representing the maximum permissible body burden is spread uniformly over 100 square feet (9.3 $m^2 \approx 10^5$ cm^2) to yield a maximum permissible surface activity. This model has the advantage of dependency on a radionuclide and permits the use of the standard practice of going from controlled area limits to uncontrolled area limits by dividing the controlled area limits by 10. The model yields a tritium maximum permissible surface contamination value of 100,000 pCi/100 cm^2 for an uncontrolled area.

In the watch casing and repair areas there appeared to be a correlation between surface, air and human contamination values. For the casing area in Firm A, these percentages were 11.2 percent, 11.6 percent and 17.3 percent of the maximum permissible values. In the repair area in Firm A, the percentages were 7.8 percent, 7.8 percent and 7.9 percent of the maximum permissible values. In these areas there were few watches in storage and the ventilation was good. Therefore, most of the air contamination probably arose from surface contamination and the correlation should not be too surprising since all of the limits are ultimately based on the tritium occupational maximum permissible body burden of 1 mCi. On the other hand, the watch storage facilities showed no correlation between surface, air, and human contamination. For Firm X, the percentages were 1.1 percent, 320 percent and 100 percent of the maximum permissible values. The general disagreement can be explained by the fact that the source of the air contamination was not primarily from surface activity but more likely from the tritium on the watches in storage. The ventilation in this facility was poor, thereby permitting a buildup in air activity from this source.

As indicated in table 8, there are two limits for alpha emitters in many jurisdictions. One set applies to alpha-emitting radionuclides of

Table 8. Some suggested removable surface contamination limits for uncontrolled areas

Radioactivity	Concentration ($\frac{\mu Ci}{cm^2}$)						
	British codes of practice[a]	AECL[a]	France CEA[a]	ORNL[a]	NCRP[b]	New York State Dept. of Labor	Based on MPBB model
Alpha emitters (very hazardous radionuclides)	10^{-5}	10^{-6}	10^{-5}	1.3×10^{-7}	4.5×10^{-7}	Average: 1.5×10^{-7}	
Alpha emitters (other radionuclides)	10^{-4}				4.5×10^{-6}	Maximum: 4.5×10^{-7}	
Beta emitters (unspecified)	10^{-4}	10^{-5}	10^{-4}	4.5×10^{-6}	(c) 100	Average: 1×10^{-6} Maximum: 5×10^{-6} (except for tritium)	
Beta emitters (tritium)						Average: 1×10^{-5} Maximum: 5×10^{-5}	1×10^{-3}

[a] As given in ICRP Publication 5 (1964) pp. 20-21.
[b] As given in NCRP Report No. 30 (NBS Handbook 92) (1965) table 6, p. 47.
[c] $\frac{cpm}{smear}$

low radiotoxicity, such as natural uranium and natural thorium, and the other value applies to all other alpha-emitting radionuclides. This is not the case with beta emitters where a single value is given which varies from 4.5×10^{-6} to 10^{-4} μCi/cm^2. (The British and French authorities sometimes list a separate value for very high-toxicity beta emitters but the value is identical to the value for other beta emitters.) The National Council on Radiation Protection and Measurements (NCRP) value of 100 cpm/smear is open to various interpretations. If one assumes the area covered by the smear is 100 cm^2 and a 50 percent geometry and efficiency factor, 100 cpm/smear is equivalent to 1×10^{-6} μCi/cm^2.

The guideline for surface contamination which we are using for all beta emitters, except tritium, is 1×10^{-6} μCi/cm^2 average and 5×10^{-6} μCi/cm^2 maximum. The inclusion of average and maximum values is more realistic than just one value. It is customary to estimate surface contamination by taking a number of smears over surfaces in the contaminated facility. The 1×10^{-6} μCi/cm^2 average and 5×10^{-6} μCi/cm^2 maximum surface contamination guidelines permit a realistic interpretation of such a survey. These values would be very difficult to live with in the case of tritium, therefore values of 10×10^{-6} μCi/cm^2 average and 50×10^{-6} μCi/cm^2 maximum were recommended for tritium. Although higher values might be justified in some cases, there are other situations, such as in a storage area, where a higher limit could be misleading.

While the results of this study indicate that monitoring an isolated parameter, such as surface contamination, could lead to misleading conclusions, it is still important to recognize that monitoring surface contamination is an important diagnostic tool in health physics. In checking on day-to-day operations it gives information on the location and source of contamination. It assists in identifying problem areas. It is a simple and relatively easy monitoring technique to use. In the case of tritium, if surface contamination is permitted to build up, there will be a gradual buildup in air activity as the tritium is covered over through cleaning, waxing and painting. Finally, at the time of vacating installations, surface contamination limits are required. Vacating facilities is not an infrequent occurrence in the industrial world; among licensed watch firms, it occurs about once per year. The final cleanup of facilities when they are vacated might be impossible to any realistic limit if the operation is not conducted under some type of surface contamination constraint. Past histories of decontamination operations have indicated many times that the real problem normally lies not with decontaminating the removable surface contamination but in reducing the fixed contamination. There is the additional possibility that too high surface contamination or even total lack of consideration of surface contamination will lead to the spread of activity to other areas via a person's hands, clothing, and shoes.

That the behavior of tritium is peculiar in the relationship between its surface and air contamination values is clearly shown in table 9. The table summarizes observed resuspension values for several radionuclides taken under a variety of conditions. The values for tritium are several orders of magnitude larger than those observed with all other radionuclides studied.

Table 9. Some resuspension factors reported in literature

Radionuclide	Conditions of measurement	Resuspension factor (cm^{-1})	Source
Uranium	Actual plant conditions	1.3×10^{-7}	Eisenbud, Blatz and Barry (*5*)
Plutonium oxide	Controlled experiments	$2 \times 10^{-10} - 5 \times 10^{-7}$	Jones and Pond (*4*)
Plutonium nitrate	Controlled experiments	$2 \times 10^{-10} - 5 \times 10^{-7}$	Jones and Pond (*4*)
Plutonium	Controlled experiment	$5 \times 10^{-7} - 1 \times 10^{-4}$	Glauberman, Bottman and Breslin (*6*)
Uranium	Controlled experiment	$2 \times 10^{-7} - 4.7 \times 10^{-6}$	Glauberman, Bottman and Breslin (*6*)
Unspecified	Actual plant conditions (new plant)	$2 \times 10^{-6} - 1 \times 10^{-5}$	Brunskill (*8*)
Unspecified	Actual plant conditions (small unventilated room)	4×10^{-5}	Brunskill (*8*)
Tritium	Actual plant conditions (storage vaults)	$2.0 \times 10^{-3} - > 2$	This paper
Tritium	Actual plant conditions (casing and repair rooms)	$3.3 \times 10^{-4} - 4.9 \times 10^{-2}$	This paper

This might be partially explained on the basis of different sampling and averaging techniques but probably most of the difference arises from tritium, in storage or inaccessible to smear detection, interacting with water vapor in the air.

Summary

Storage vaults of 11 firms (nine wholesale-importer and two retailers) were surveyed three times over an 11-month period. A range of air, surface, and human contamination was found which depended on a variety of factors. The principal factors appeared to be the quantity of tritium in storage and the degree of ventilation in the vault. The highest human exposure was observed in an individual working in a poorly ventilated vault through which moved about 200 Ci of tritium annually. At the retail level, two storage areas had negligible contamination.

The casing and repair areas of two firms were surveyed monthly over a 12-month period. The firm handling 142 Ci of tritium on an annual basis in the casing area had an average surface contamination of 11,200 pCi/100 cm^2, but air and human contamination were a modest 0.058 pCi/cm^3 and 0.48 μCi/liter. The repair area of this firm, handling 137 Ci of tritium annually, had average surface contamination of 7,820 pCi/100 cm^2 but air and human contamination were a modest 0.039 pCi/cm^3 and 0.22 μCi/liter. The casing area of the firm handling 10.5 Ci of tritium annually had air, surface, and human contamination of background, 430 pCi/100 cm^2 and 0.08 μCi/liter, respectively. This firm handled 7.5 Ci of tritium in its repair area where air, surface, and human contamination was background, 807 pCi/100 cm^2 and 0.05 μCi/liter, respectively.

One watch refinisher was surveyed over a 12-month period. An estimate of 30-50 Ci of tritium annually was stripped off hands and dials. The area near the stripping solution had average surface contamination of 33,600 pCi/100 cm^2 but negligible air and human contamination was found.

To control the spread of tritium contamination and to head off future problems in tritium decontamination, surface contamination limits of 1,000 pCi/100 cm^2 average and 5,000 pCi/100 cm^2 maximum, were adopted.

Resuspension values found with tritium were in the range of 2.0×10^{-3} to >2 cm^{-1} for the storage area and in the range of 3.3×10^{-4} to 4.9×10^{-2} cm^{-1} for the casing and repair areas. The range of resuspension values are higher than those found with other radionuclides. The difference may be the result of different experimental techniques but may also be attributable to the buildup of tritium in the atmosphere as a result of the exchange of water vapor in the air with tritium on watches. This tritium is not accounted for in the usual definition of resuspension factor and may contribute to the higher values.

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REFERENCES

(1) JONES, H. G. and B. E. LAMBERT. The radiation hazard to workers using tritiated luminous compounds (SM-52/21). Assessment of Radioactivity in Man, International Atomic Energy Agency, Vienna (1964) pp. 419–430.

(2) MOGHISSI, A. A., E. D. TOERBER, J. E. REGNIER, M. W. CARTER, and C. D. POSEY. Health physics aspects of tritium luminous dial painting. Health Physics 18:225–261 (March 1970).

(3) BUTLER, F. E. Assessment of tritium in production workers (SM-52/33). Assessment of Radioactivity in Man, International Atomic Energy Agency, Vienna (1964) pp. 431–442.

(4) JONES, I. S. and S. F. POND. Some experiments to determine the resuspension factor of plutonium from various surfaces. Surface Contamination, Proceedings of a Symposium, Gatlinburg, Tenn., June 1964. Pergamon Press, Oxford (1967) pp. 83–92.

(5) EISENBUD, M., H. BLATZ, and E. V. BARRY. How important is surface contamination? Nucleonics 12:12-15 (August 1954).

(6) GLAUBERMAN, H., W. R. BOTTMAN, and A. J. BRESLIN. Studies of the significance of surface contamination. Surface Contamination, Proceedings of a Symposium, Gatlinburg, Tenn., June 1964. Pergamon Press, Oxford (1967) pp. 169–178.

(7) DUNSTER, H. J. The concept of derived working limits for surface contamination. Surface Contamination, Proceedings of a Symposium, Gatlinburg, Tenn., June 1964. Pergamon Press, Oxford (1967) pp. 139–147.

(8) BRUNSKILL, R. T. The relationship between surface and air contamination. Surface Contamination, Proceedings of a Symposium, Gatlinburg, Tenn., June 1964. Pergamon Press, Oxford (1967) pp. 93–105.

Technical Notes

Consideration of Stable Iodine in the Environment in the Evaluation of Maximum Permissible Concentrations for Iodine-129

Jacob Tadmor[1]

In evaluating the hazards to man resulting from internal irradiation due to inhalation or ingestion of radioisotopes, only one pathway at a time is considered in presenting the maximum permissible concentrations (MPC). It is generally assumed that the physical, chemical, and biological behavior of the radioisotopes is similar to that of the corresponding stable elements. Much of the behavior of radioactive isotopes in an equilibrated environment (for instance, the extent of their assimilation and concentration in different organs of the human body) of limited content of the element could be influenced by the specific activity of the radionuclide, i.e., the ratio between the mass concentration of radioactive and total (radioactive and stable) isotopes present. This is especially true in the case of a routine and continuous release of radioisotopes to the environment. Therefore, in establishing the MPC for a radionuclide, it is important to consider the ratio between the concentrations of the radioactive and total isotopes in an environment in equilibrium with a source of a radionuclide release, i.e., in which all pathways by which a man may take in a radionuclide (air, water, food, etc.) are in equilibrium with it (*1*).

The specific activity concept in recommending maximum permissible concentrations of radionuclides has been suggested by the National Academy of Sciences (*2*) and applied by several authors (*3-7*).

In the present study, an example is presented showing the influence of the concentration of stable elements on the assimilation and concentration of radioactive material in the human body in an environment which is assumed to be in equilibrium with a source of a radionuclide release.

Evaluation of MPC's for radionuclides

Consideration of the relationship between the concentration of stable and radioactive isotopes in an equilibrated environment reveals that a revision of the MPC's established for certain radioisotopes may be in order.

Consider a radioisotope of which the mass concentration corresponding to the MPC is high relative to that of the stable element in the environment. Assume that the same ratio exists at equilibrium in the human body. This is true for radionuclides having a long half-life, so that the radioactive decay constant is negligible compared to the biological elimination constants in the food chains leading to human intake. Then, the actual radioisotope burden in the critical organ, following the establishment of an equilibrium state, may exceed the maximum permissible burden established by the radiation and MPC limitation. In this case, the MPC should be reduced according to the equilibrium ratio between the radioactive and total isotopes in the environment and critical organ. Consideration should also be given to the potential toxicological effects of an increased mass concentration of the element in the environment (*8*).

A test computation was performed on the MPC in air of iodine-129 and the corresponding maximum permissible burden in the thyroid, taking into consideration the ratio between the mass concentration of the radioactive and total isotopes.

Adams and Bonnell (*9*) and Colard et al. (*10*) have shown that ingestion of inorganic iodide would significantly reduce the dose to

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the thyroid due to concurrently inhaled radioactive iodine. It was also indicated (*10*) that the iodine-saturated thyroid gland will not take up more activity from a new feeding of iodide, which will be completely excreted by the kidneys. The possible influence of stable iodine on the rate of reaction and ultimate fate of radioactive iodine in the environment has also been discussed by Cowser (*11*). These results indicate that, because of the limited content of iodine in the thyroid, a relatively high mass concentration of radioactive iodine would reduce the amount of stable iodine, up to the saturation of the thyroid with radioactive iodine.

A continuous release of iodine-129 to the atmosphere may be envisaged following the expansion of the nuclear industry, mainly that of the nuclear fuel reprocessing plants. It is assumed (*12*) that a 10 tons/day fuel reprocessing plant is representative of the size which would be needed by the year 2000 in an area of high concentration of nuclear reactors. The release of iodine-129 from the reprocessing without any separation factor would be 0.33 Ci/day for a burnup of 20,000 Mwd/ton (*13*). In order to stress the need of ensuring efficient removal of iodine-129 from stack gases, it is assumed, for illustrative purposes, that about 90 percent of the iodine-129 contained in spent nuclear fuel is released to the atmosphere in a nuclear fuel reprocessing plant (*14*). Assuming a release of iodine-129 at a height of 50 m, the average annual concentration in the environment, along a 22.5° arc, at the region of maximum concentration (1 to 5 km) would be of the order of 10^{-11} Ci/m^3 (*15*), which approaches the nonoccupational (168 h-week) MPC in air for iodine-129, i.e. 6×10^{-11} Ci/m^3 (thyroid as critical organ). The nonoccupational MPC in air is considered as 1/10 of the occupational limit (*16, 17*).

Assume that the environment of a fuel reprocessing plant has a continuous air concentration of iodine-129 equal to 6×10^{-11} Ci/m^3. The specific activity of iodine-129 is 1.6×10^{-4} Ci/g (6.24×10^3 g/Ci). Thus, the iodine-129 mass concentration corresponding to the MPC is 3.7×10^{-7} g/m^3. Together with iodine-129, stable iodine is also released from nuclear fuel reprocessing plants. The ratio of $^{129}I/^{127}I$ in spent fuel, after 1 year cooling, being 0.75, the concentration of stable iodine at the region of maximum concentration would be of the order of 10^{-7} g/m^3.

This concentration of stable iodine in air is assumed to be representative for otherwise unpolluted air and is taken for illustrative purposes, although a wide variability of concentrations is encountered in different areas. Thus, a concentration of 5×10^{-9} g/m^3 is indicated for unpolluted air (*18*), while a range of 0 to 7×10^{-6} g/m^3 is indicated by others (*19*) for the concentration of stable iodine. For other specific values of stable iodine concentrations, different from that assumed in the present study, the calculations should be made using the local data of the individual cases.

Considering a long-lived radioisotope such as iodine-129 being released continuously to the atmosphere, it is assumed that, at environmental equilibrium established after long-time release of iodine-129, the ratio between iodine-129 and total iodine as found in air would exist also in other pathways by which man may take in a radionuclide.

Iodine-129, being continuously released to the environment, is also being deposited on surface water, soil, and vegetation, which become equilibrated with the iodine of the atmosphere (*20, 21*). Table 1 shows the half time to equilibrium for iodine-129 via different pathways and for various human tissues, as compiled by Pratt (*21*). It was also found (*22*) that the delay between the appearance of a peak in vegetation and its appearance in milk is only several days, and that fresh milk is one of the principal modes of intake of radioiodine in an area where relatively high concentrations of the radioiodine exist. Moreover, a "reconcentration factor" or rather an MPC_a reducing factor of up to 700 is recommended (*23-25*) for radioactive iodine, when considering the pasture deposition—milk exposure pathway.

Similarly to milk, other pathways of iodine intake in man are also assumed to be equilibrated with the iodine in the atmosphere. Thus, Russell and Hahn (*26*) indicated that a weed sample collected in Cattaraugus Creek, about 1 mile downstream of Nuclear Fuel Services

Table 1. Half time to equilibrium for iodine-129 in various pathways

Pathway	Organ	Half time to equilibrium (days)	
		Adult	Child
Sea water and fresh water	Bone	14	2
Milk	Bone	35	14
Milk	Whole body	167	14
Sea water and fresh water	Whole body	138	19.7
Soil	Bone and whole body	2.78×10^6	2.53×10^6

discharge contained 0.81 μCi ^{129}I/g of total iodine. This would cause about 10 percent of the Federal Radiation Council (FRC) guidance for the maximum dose to man's thyroid, assuming that the ratio of iodine-129 to stable iodine is at equilibrium throughout the chain. Also, Ng and Thompson (*27*) assumed, in a study of the radiation doses from internal emitters, that radionuclides deposited on ground and vegetation equilibrate fast within the biological exchangeable pool.

It is also assumed that all the iodine supply to the population, i.e., from air, as well as from food items such as milk, vegetables, etc., is provided by the environment nearby to the release source of iodine-129 (up to about 5 km), in which the ratio of iodine-129 concentration to that of total iodine is relatively high.

The average total iodine content in the normal thyroid is 7×10^{-3} g (*16*). Assuming that all pathways of intake of iodine are equilibrated with the iodine in the atmosphere, the thyroid would contain at equilibrium mostly (75 percent) iodine-129. Thus, its iodine-129 thyroid burden corresponding to the MPC would be:

(7.5×10^{-1}) $(7 \times 10^{-3}$ g) $(1.6 \times 10^{-4}$ Ci/g) = 8.4×10^{-7} Ci.

In comparison with the estimated thyroid burden of 8.4×10^{-7} Ci, the maximum permissible burden of iodine-129 in the total human body for the nonoccupational population (thyroid as critical organ), established by the radiation limit and MPC, is 3×10^{-7} Ci (*17*) and the corresponding thyroid permissible burden (considering $f_2 = 0.2$) is 6×10^{-8} Ci.[2]

[2] f_2 = fraction of the radionuclide in the critical organ of that in total body.

It thus appears that, by establishing an MPC_a for iodine-129 of 6×10^{-11} Ci/m^3 for the nonoccupational population, the human thyroid burden would reach a level of about fourteenfold higher than the maximum permissible burden. Consequently, the nonoccupational MPC in air should be lowered to a value which would yield a fourteenfold reduction in the iodine-129 specific activity at equilibrium within the thyroid, i.e. 5.4 percent instead of 75 percent, so that the maximum permissible burden in the thyroid is not exceeded.

The corresponding iodine-129 burden in the thyroid would then be:

$(7 \times 10^{-3}$ g) (5.4×10^{-2}) $(1.6 \times 10^{-4}$ Ci/g) = 6×10^{-8} Ci, which is the thyroid permissible burden.

Assuming an average concentration of 10^{-7} g/m^3 of stable iodine in air and for a specific activity of 5.4 percent of iodine-129, the mass concentration of iodine-129 in air is calculated to be 5.4×10^{-9} g/m^3 and the corresponding activity concentration is 8.6×10^{-13} Ci/m^3, which should be the recommended reduced MPC.

A value of 8.4×10^{-13} Ci/m^3, similar to the MPC suggested in the present study for iodine-129 in air, is also calculated using the specific activity models proposed in references 2, 3, and 5.

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REFERENCES

(*1*) TADMOR, J. and K. E. COWSER. Effect of stable elements in the environment on the maximum permissible concentration of radionuclides, IA-1190. IAEC Research Laboratories Annual Report, January-December 1968 (1969) p. 248.

(*2*) NATIONAL ACADEMY OF SCIENCES, NATIONAL RESEARCH COUNCIL. The biological effects of atomic radiation, summary report. National Research Council, Washington, D.C. (1960).

(*3*) NATIONAL ACADEMY OF SCIENCES, NATIONAL RESEARCH COUNCIL. Disposal of low-level radioactive waste into Pacific Coastal waters, Publication 985. National Research Council, Washington, D.C. (1962).

(*4*) DYSON, E. D. A specific activity method for derived working limits of phosphorus-32. Health Phys 12:1521 (1966).

(5) KAYE, S. W. and D. J. NELSON. Analysis of specific activity concept as related to environmental concentration of radionuclides. Nucl Safety 9:53 (1968)
(6) BRYANT, P. M. Derivation of working limits for continuous release rates of ^{129}I to atmosphere. Health Phys 19:611 (1970).
(7) REICHLE, D. E., P. B. DUNAWAY, and D. J. NELSON. Turnover and concentration of radionuclides in food chains. Nucl Safety 11:43 (1970).
(8) INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION. Recommendations of the International Commission on Radiological Protection, ICRP Publication 6. Pergamon Press, New York, N.Y. (1964) p. 40.
(9) ADAMS, C. A. and J. A. BONNELL. Administration of stable iodide as a means of reducing thyroid irradiation resulting from inhalation of radioactive iodine. Health Phys 7:127 (1962).
(10) COLARD, F. A., W. G. VERLY et al. Fate of the iodine radioisotopes in the human and the estimation of the radiation exposure. Health Phys 11:23 (1965).
(11) COWSER, K. E. Current practices in the release and monitoring of ^{131}I at NRTS, Hanford, Savannah River and ORNL, ORNL-NSIC-3. Oak Ridge National Laboratory (1964).
(12) TADMOR, J. and K. E. COWSER. Underground disposal of krypton-85 from nuclear fuel reprocessing plants. Nucl Engr Design 6:243 (1967).
(13) FERGUSON, D. E. and R. E. BLANCO. General survey of reprocessing of thermal reactor fuels. Proceedings of the American Nuclear Society International Meeting, Washington, D.C. (November 1968).
(14) COCHRAN, J. A. et al. An investigation of airborne radioactive effluent from an operating nuclear fuel reprocessing plant, BRH/NERHL 70-3. Bureau of Radiological Health, Northeastern Radiological Health Laboratory, Winchester, Mass. (1970).
(15) TADMOR, J. Consideration of deposition of pollutants in the design of a stack height. Atmospheric Environ 5:473 (1971).
(16) INTERNATIONAL ATOMIC ENERGY AGENCY. Basic safety standards for radiation protection, IAEA Safety Series No 9. (1967) p. 32.
(17) INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION. Report of ICRP Committee II on permissible dose for internal radiation. Health Phys 3:60 (1960).
(18) LININGER, R. L. et al. Chlorine, bromine, iodine and lead in aerosols from Cambridge, Massachusetts. J Geophys Res 71:2457 (1966).
(19) EGGLETON, A. E. J. et al. Chemical and physical nature of fallout ^{131}I and carrier-free ^{131}I released in air—an abstract. Health Phys 9:1111 (1963).
(20) BOLIN, B. Note on the exchange of iodine between the atmosphere, land and sea. Int J Air Pollut 2:127 (1959).
(21) PRATT, M. W. Prediction of the maximum dosage to man from the fallout of nuclear devices, Part VII, UCRL 50163, Lawrence Radiation Laboratory, University of California, Livermore (November 1970).
(22) SOLDAT, J. K. The relationship between ^{131}I concentrations in various environmental samples. Health Phys 9:1167 (1963).
(23) BURNET, T. J. A derivation of the factor of 700 for ^{131}I. Health Phys 18:73 (1970).
(24) HULL, A. P. Invited comments on a derivation of the factor of 700 for ^{131}I. Health Phys 19:696 (1970).
(25) GEORGE, K. D. ^{131}I reconcentration factor. Health Phys 19:699 (1970).
(26) RUSSELL, J. L. and P. B. HAHN. Public health aspects of iodine-129 from the nuclear power industry. Paper presented at the Fifth Annual Health Physics Society Mid-year Symposium, Idaho Falls (November 1970).
(27) NG, Y. C. and S. E. THOMPSON. Prediction of the maximum dosage to man from the fallout of nuclear devices, Part II, UCRL 50163. Lawrence Radiation Laboratory, University of California, Livermore (December 1966).

Strontium-90 and Cesium-137 in Canned Seafood, Taiwan, Republic of China, 1970–1971

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Since 1970, canned seafood available on the market has been regularly monitored for strontium-90 and cesium-137 radioactivity. Tsing Hua University analyzed the samples by means of standard radiochemical methods and beta-particle counting in a low, background counting system.

The samples included canned seafood from Europe, North America, Japan, and Taiwan as well as a wide variety of seafood extending from sardines to seaweeds. No exceptionally high radioactivity was detected during 1970-1971 period. The mean concentration of strontium-90 was 0.14 ± 0.03 pCi/g ash and that of cesium-137, 0.17 ± 0.05 pCi/g ash. The ratio cesium-137/strontium-90 was 1.21 ± 0.44. The results of the analyses are presented in table 1 and plotted in figure 1.

The table and figure show that there is no significant difference in the fallout content among the samples analyzed. As compared with fresh fish, such as neothunnus macropterus, white dorads, stromateoides argenteus, red snapper, dorade, and thunnus thynnus available in Taiwan, the gross beta radioactivity in canned fish (sardines, herrings, mackerels, salmon, pacific saury, maguro, tuna, and bonita) was 0.61 of that in fresh fish. In other words, the fresh sea fish contained more gross beta radioactivity in pCi/g ash than the canned seafood.

Other canned seafood, such as deep sea shellfish, snow crab meat, baked bloody clams skewered, ark shell, laver, top shells, and lobster, show a lower gross beta radioactivity than canned fish. The gross beta ratio of shellfish to fish is 0.33.

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Table 1. Strontium-90 and cesium-137 levels in canned seafoods, 1970–1971

Sample number	Seafood and country of origin	Net weight wet (g)	Ash weight (g)	Potassium $\left(\frac{mg}{100\ mg\ ash}\right)$	Cesium-137 $\left(\frac{pCi}{g\ ash}\right)$	Potassium-40 $\left(\frac{pCi}{kg}\right)$ (wet weight)	$^{137}Cs/K$ $\left(\frac{pCi}{g}\right)$	Calcium $\left(\frac{mg}{100\ mg\ ash}\right)$	Strontium-90 $\left(\frac{pCi}{g\ ash}\right)$
1	Sardines, U.S.A.	425	12.3815	14.60	0.24±0.16	4.25	6.99	4.89	0.18±0.16
2	Deep sea shellfish, Mexico	855	18.8775	12.65	.18± .15	2.79	3.97	[a].97	.16± .15
3	Sardines, Canada	96	2.6899	11.09	.18± .15	3.11	5.04	4.79	.14± .15
4	Herring, Germany	780	27.3177	14.02	.14± .16	4.91	4.90	4.37	.14± .15
5	Herring, United Kingdom	1,185	32.9485	7.87	.16± .15	2.19	4.45	5.22	.16± .15
6	Baby mackerel, Portugal	125	3.7842	14.71	.26± .15	4.45	7.87	4.53	.21± .16
7	Mackerel, Japan	425	9.9772	14.87	.26± .16	3.49	6.10	4.23	.16± .15
8	Snow crab meat, Japan	730	28.0061	4.48	.13± .15	1.72	4.99	4.51	.16± .15
9	Salmon, Japan	1,080	31.3788	14.17	.13± .16	4.11	3.78	6.59	.14± .16
10	Pacific saury, Japan	980	45.0898	4.37	.15± .15	2.01	6.90	3.52	.14± .16
11	Baked bloody clams skewered, Japan	1,000	29.4228	2.85	.11± .15	.84	3.24	[a]1.09	.13± .16
12	Mackerel, Japan	220	5.6444	13.06	.22± .15	3.35	5.64	4.09	.13± .15
13	Ark shell, Japan	890	30.0114	15.32	.15± .16	5.16	5.06	[a]1.26	.13± .15
14	Mackerel, Japan	220	5.9288	11.35	.20± .15	3.05	5.39	3.71	.12± .15
15	Maguro, Japan	280	8.3920	11.76	.19± .15	3.52	5.69	[a]1.40	.12± .16
16	Laver, Japan	1,200	43.1424	3.50	.11± .15	1.26	3.95	[a].46	.11± .14
17	Laver and fish, Japan	1,095	39.8918	11.97	.11± .15	4.36	4.01	[a].81	.11± .14
18	Top shells, Japan	1,100	36.5368	3.99	.11± .15	1.33	3.65	[a].46	.11± .15
19	Tuna, Taiwan	200	3.9090	7.03	.16± .17	1.37	3.13	[a].32	.10± .15
20	Lobster, Taiwan	520	39.7479	8.02	.13± .15	6.13	9.94	3.55	.13± .15
21	Tuna, Taiwan	200	4.8387	12.58	.20± .16	3.04	4.84	[a].33	.15± .14
22	Bonito, Taiwan	870	25.2898	11.80	.25± .17	3.43	7.27	5.04	.20± .16

[a] Without bone.

Table 1. Strontium-90 and cesium-137 levels in canned seafoods, 1970–1971—continued

Sample number	Seafood and country of origin	Calcium $\left(\frac{g}{kg}\right)$ (wet weight)	Strontium-90 $\left(\frac{pCi}{kg}\right)$ (wet weight)	$\frac{^{90}Sr}{Ca}$ $\left(\frac{pCi}{g}\right)$	$\frac{^{137}Cs}{^{90}Sr}$	$\frac{^{90}Sr}{^{137}Cs}$	Gross beta $\left(\frac{pCi}{g\ ash}\right)$	Gross beta $\left(\frac{pCi}{g}\right)$ (wet weight)
1	Sardines, U.S.A.	1.42	5.24	3.69	1.33	0.75	113.74	3.31
2	Deep sea shellfish, Mexico	.21	3.53	16.81	1.13	.89	57.12	1.26
3	Sardines, Canada	1.32	3.92	2.97	1.28	.78	72.75	2.04
4	Herring, Germany	1.53	4.90	3.20	1.00	1.00	32.97	1.15
5	Herring, United Kingdom	1.45	4.45	3.07	1.00	1.00	82.21	2.29
6	Baby mackerel, Portugal	1.37	6.36	4.64	1.24	.81	126.80	3.84
7	Mackerel, Japan	.99	3.76	3.80	1.62	.62	132.21	3.11
8	Snow crab meat, Japan	1.73	6.14	3.55	.81	1.23	23.20	.89
9	Salmon, Japan	1.91	4.07	2.13	.93	1.08	25.76	.75
10	Pacific saury, Japan	1.62	6.44	3.98	1.07	.93	47.98	2.21
11	Baked bloody clams skewered, Japan	.32	3.83	11.97	.85	1.18	15.77	.46
12	Mackerel, Japan	1.05	3.34	3.18	1.69	.59	133.56	3.43
13	Ark shell, Japan	.42	4.38	10.43	1.15	.87	24.95	.84
14	Mackerel, Japan	1.00	3.23	3.23	1.67	.60	79.05	2.13
15	Maguro, Japan	.42	3.60	8.57	1.58	.63	67.57	2.03
16	Laver, Japan	.17	3.95	23.24	1.00	1.00	21.85	.79
17	Laver and fish, Japan	.30	4.01	13.37	1.00	1.00	19.59	.71
18	Top shells, Japan	.15	3.65	24.33	1.00	1.00	24.10	.80
19	Tuna, Taiwan	.06	1.95	32.50	1.60	.63	87.84	1.72
20	Lobster, Taiwan	2.71	9.94	3.67	1.00	1.00	28.29	2.16
21	Tuna, Taiwan	.08	3.63	45.37	1.33	.75	93.69	2.26
22	Bonito, Taiwan	1.46	5.81	3.98	1.25	.80	50.99	1.48

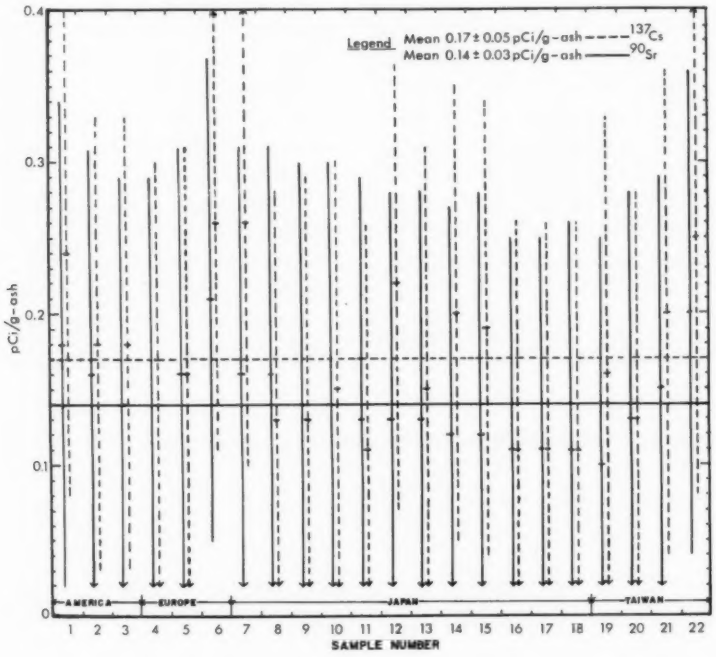

Figure 1. Strontium–90 and cesium–137 levels in canned seafood

SECTION I. MILK AND FOOD

Milk Surveillance, August 1971

Although milk is only one of the sources of dietary intake of environmental radioactivity, it is the food item that is most useful as an indicator of the general population's intake of radionuclide contaminants resulting from environmental releases. Fresh milk is consumed by a large segment of the population and contains several of the biologically important radionuclides that may be released to the environment from nuclear activities. In addition, milk is produced and consumed on a regular basis, is convenient to handle and analyze, and samples representative of general population consumption can be readily obtained. Therefore, milk sampling networks have been found to be an effective mechanism for obtaining information on current radionuclide concentrations and long-term trends. From such information, public health agencies can determine the need for further investigation or corrective public health action.

The Pasteurized Milk Network (PMN) sponsored by the Office of Radiation Programs, Environmental Protection Agency, and the Office of Food Sanitation, Food and Drug Administration, U.S. Public Health Service, consists of 63 sampling stations: 61 located in the United States, one in Puerto Rico, and one in the Canal Zone. Many of the State health departments also conduct local milk surveillance programs which provide more comprehensive coverage within the individual State. Data from 15 of these State networks are reported routinely in *Radiological Health Data and Reports.* Additional networks for the routine surveillance of radioactivity in milk in the Western Hemisphere and their sponsoring organizations are:

Pan American Milk Sampling Program (Pan American Health Organization and U.S. Environmental Protection Agency)—5 sampling stations

Canadian Milk Network (Radiation Protection Division, Canadian Department of National Health and Welfare)—16 sampling stations.

The sampling locations that make up the networks presently reporting in *Radiological Health Data and Reports* are shown in figure 1. Based on the similar purpose for these sampling activities, the present format integrates the complementary data that are routinely obtained by these several milk networks.

Radionuclide and element coverage

Considerable experience has established that relatively few of the many radionuclides that are formed as a result of nuclear fission become incorporated in milk (*1*). Most of the possible radiocontaminants are eliminated by the selective metabolism of the cow, which restricts gastrointestinal uptake and secretion into the milk. The five fission-product radionuclides which commonly occur in milk are strontium-89, strontium-90, iodine-131, cesium-137, and barium-140. A sixth radionuclide, potassium-40, occurs naturally in 0.0118 percent (*2*) abundance of the element potassium, resulting in a specific activity for potassium-40 of 830 pCi/g total potassium.

Two stable elements which are found in milk, calcium and potassium, have been used as a means for assessing the biological behavior of metabolically similar radionuclides (radiostron-

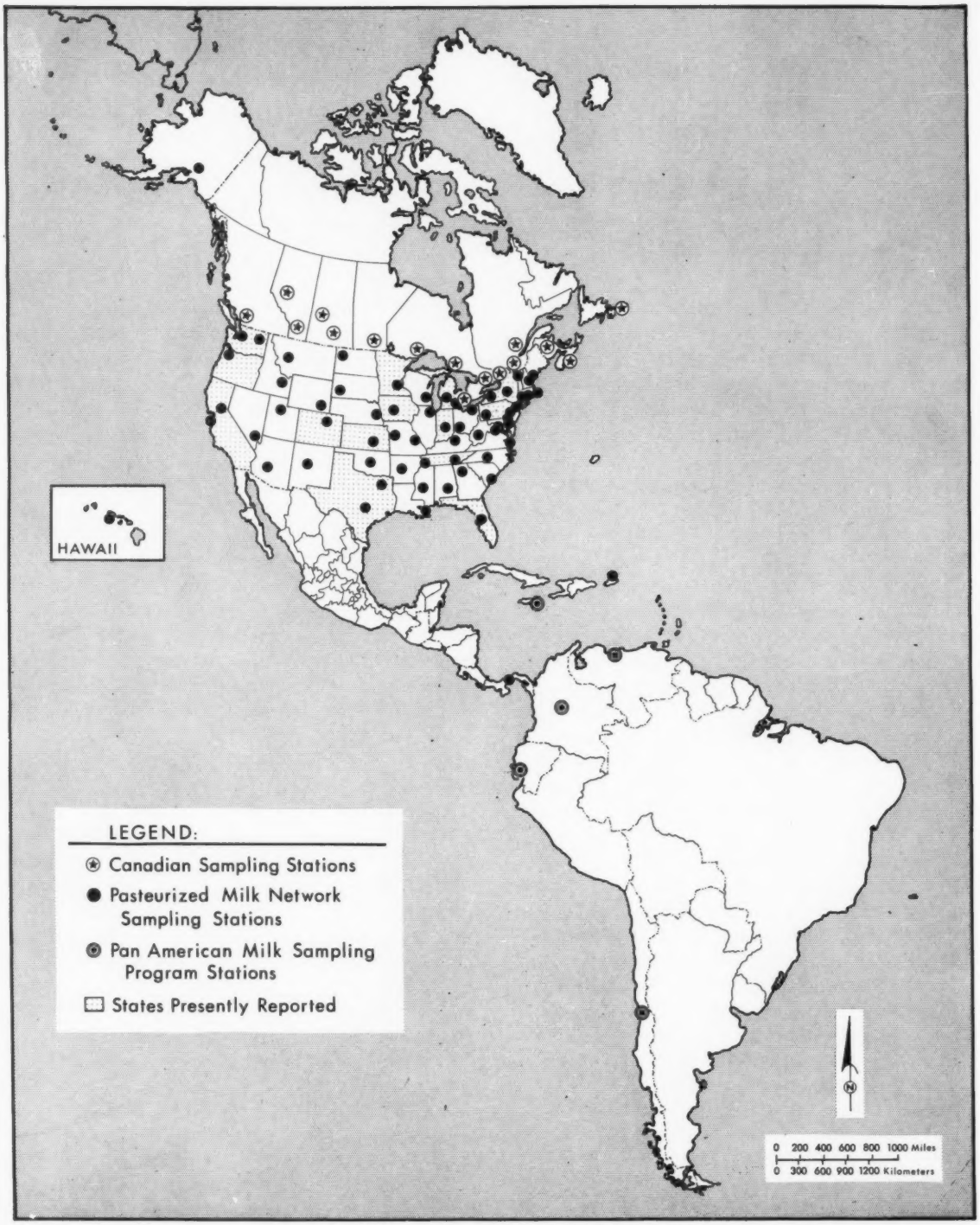

Figure 1. Milk sampling networks in the Western Hemisphere

tium and radiocesium, respectively). The contents of both calcium and potassium in milk have been measured extensively and are relatively constant. Appropriate values and their variations, expressed in terms of 2 standard deviations (2σ), for these elements are 1.16 ± 0.08 g/liter for calcium and 1.51 ± 0.21 g/liter for potassium. These figures are averages of data from the PMN for May 1963-March 1966 (*3*) and were determined for use in general radiological health calculations or discussions.

Accuracy of data from various milk networks

In order to combine data from the international, national, and State networks considered in this report, it was first necessary to determine the accuracy with which each laboratory is making its determinations and the agreement of the measurements among the laboratories. The Analytical Quality Control Service of the Office of Radiation Programs conducts periodic studies to assess the accuracy of determinations of radionuclides in milk performed by interested radiochemical laboratories. The generalized procedure for making such a study has been outlined previously (*4*).

The most recent study was conducted during May-July 1970, with 28 laboratories participating in an experiment on milk samples containing known concentrations of strontium-89, strontium-90, iodine-131, cesium-137, and barium-140 (*5*). Of the 18 laboratories producing data for the networks reporting in *Radiological Health Data and Reports*, 13 participated in the experiment.

The accuracy results of this experiment are shown in table 1. In general, considerable improvement is needed, especially in the accuracy measurements. These possible differences should be kept in mind when considering the integration of data from the various networks.

Development of a common reporting basis

Since the various networks collect and analyze samples differently, a complete understanding of several parameters is useful for interpreting the data. Therefore, the various milk surveillance networks that report regularly were surveyed for information on analytical methods, sampling and analysis frequencies, and estimated analytical errors associated with the data.

In general, radiostrontium is collected by an ion-exchange technique and determined by beta-particle counting in low-background detectors, and the gamma-ray emitters (potassium-40, iodine-131, cesium-137, and barium-140) are determined by gamma-ray spectroscopy of whole milk. Each laboratory has its own modifications and refinements of these

Table 1. Distribution of mean results, quality control experiment

Isotope and known concentration	Number of laboratories in each category			
	Acceptable [a]	Warning level [b]	Unacceptable [c]	Total
Strontium-89: High (258 pCi/liter)	7 (44%)	1 (6%)	8 (50%)	16
Low (15 pCi/liter)	11 (69%)	3 (19%)	2 (12%)	16
Strontium-90: Intermediate (79.4 pCi/liter)	13 (57%)	4 (17%)	6 (26%)	23
Low (32.0 pCi/liter)	5 (25%)	4 (20%)	11 (55%)	20
Iodine-131: High (507 pCi/liter)	18 (67%)	2 (7%)	7 (26%)	27
Low (49 pCi/liter)	16 (64%)	3 (12%)	6 (24%)	25
Cesium-137: High (259 pCi/liter)	20 (74%)	3 (11%)	4 (15%)	27
Low (53 pCi/liter)	17 (66%)	5 (19%)	4 (15%)	26
Barium-140: High (302 pCi/liter)	18 (67%)	2 (7%)	7 (26%)	27
Low (33 pCi/liter)	23 (92%)	0	2 (8%)	25

[a] Measured concentration equal to or within 2σ of the known concentration.
[b] Measured concentration outside 2σ and equal to or within 3σ of the known concentration.
[c] Measured concentration outside 3σ of the known concentration.

basic methodologies. The methods used by each of the networks have been referenced in earlier reports appearing in *Radiological Health Data and Reports*.

A previous article (*6*) summarized the criteria used by the State networks in setting up their milk sampling activities and their sample collection procedures as determined during a 1965 survey. This reference and an earlier data article for the particular network of interest may be consulted should events require a more definitive analysis of milk production and milk consumption coverage afforded by a specific network.

Many networks collect and analyze samples on a monthly basis. Some collect samples more frequently but composite the several samples for one analysis, while others carry out their analyses more often than once a month. Many networks are analyzing composite samples on a quarterly basis for certain nuclides. The frequency of collection and analysis varies not only among the networks but also at different stations within some of the networks. In addition, the frequency of collection and analysis is a function of current environmental levels. The number of samples analyzed at a particular sampling station under current conditions is reflected in the data presentation. Current levels for strontium-90 and cesium-137 are relatively stable over short-time periods, and sampling frequency is not critical. For the short-lived radionuclides, particularly iodine-131, the frequency of analysis is critical and is generally increased at the first measurement or recognition of a new influx of this radionuclide.

The data in table 2 show whether raw or pasteurized milk was collected. An analysis (*7*) of raw and pasteurized milk samples collected during January 1964 to June 1966 indicated that for relatively similar milkshed or sampling areas, the differences in concentration of radionuclides in raw and pasteurized milk are not statistically significant (*7*). Particular attention was paid to strontium-90 and cesium-137 in that analysis.

Practical reporting levels were developed by the participating networks, most often based on 2-standard-deviation errors or 2-standard-deviation total analytical errors from replicate analyses (*3*). The practical reporting level reflects analytical factors other than statistical radioactivity counting variations and will be used as a practical basis for reporting data.

The following practical reporting levels have been selected for use by all networks whose practical reporting levels were given as equal to or less than the given value.

Radionuclide	Practical reporting level (pCi/liter)
Strontium-89	5
Strontium-90	2
Iodine-131	10
Cesium-137	10
Barium-140	10

Some of the networks gave practical reporting levels greater than those above. In these cases, the larger value is used so that only data considered by the network as meaningful will be presented. The practical reporting levels apply to the handling of individual sample determinations. The treatment of measurements equal to or below these practical reporting levels for calculation purposes, particularly in calculating monthly averages, is discussed in the data presentation.

Analytical error or precision expressed as pCi/liter or percent in a given concentration range has also been reported by the networks (*3*). The precision errors reported for each of the radionuclides fall in the following ranges:

Radionuclide	Analytical errors of precision (2-standard deviations)
Strontium-89	1-5 pCi/liter for levels <50 pCi/liter; 5-10% for levels ≥ 50 pCi/liter;
Strontium-90	1-2 pCi/liter for levels <20 pCi/liter; 4-10% for levels ≥ 20 pCi/liter;
Iodine-131, Cesium-137, Barium-140	4-10 pCi/liter for levels <100 pCi/liter; 4–10% for levels ≥ 100 pCi/liter.

For iodine-131, cesium-137, and barium-140, there is one exception for these precision error ranges: 25 pCi/liter at levels <100 pCi/liter

Table 2. Concentrations of radionuclides in milk for August 1971 and 12-month period, September 1970 through August 1971

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average
UNITED STATES:								
Ala:	Montgomery[c]	P	NA	7	0	0	15	10
Alaska:	Palmer[c]	P	5	5	0	0	22	13
Ariz:	Phoenix[c]	P	NA	1	0	0	0	0
Ark:	Little Rock[c]	P	16	12	0	0	0	11
Calif:	Sacramento[c]	P	NA	1	0	0	0	0
	San Francisco[c]	P	NA	4	0	0	0	0
	Del Norte	P	16	15	0	0	10	11
	Fresno	P	0	2	0	0	0	2
	Humboldt	P	NA		NA		NA	
	Los Angeles	P	0	2	0	0	0	0
	Mendocino	P	5	6	0	0	0	5
	Sacramento	P	3	3	0	0	0	2
	San Diego	P	0	1	0	0	0	1
	Santa Clara	P	2	2	0	0	0	1
	Shasta	P	3	3	0	0	10	4
	Sonoma	P	2	3	0	0	0	3
Colo:	Denver[c]	P	NA	4	0	0	0	6
	West	R	(d)		≤0	≤0	≤0	≤0
	Northeast	R	(d)		≤0(2)	≤0	≤0(2)	≤1
	East	R	(d)		NS	≤0	NS	≤0
	Southeast	R	(d)		NS	NS	NS	NS
	South Central	R	(d)		≤0	≤0	≤0	≤0
	Southwest	R	(d)		≤0	≤0	≤0	≤3
	Northwest	R	(d)		NS	≤0	NS	≤0
Conn:	Hartford[c]	P	NA	7	0	0	18	11
	Central	P	7	7	0	0	13	16
Del:	Wilmington[c]	P	NA	9	0	0	0	6
D.C:	Washington[c]	P	NA	7	0	0	12	9
Fla:	Tampa	P	5	5	0	0	38	45
	Central	R	8	6	0	0	11	36
	North	R	18	8	0	0	27	26
	Northeast	R	11	7	0	0	41	36
	Southeast	R	6	7	0	1	23	68
	Tampa Bay area	P	6	6	0	0	34	45
	West	R	11	10	0	0	12	17
Ga:	Atlanta[c]	P	NA	11	0	0	16	14
Hawaii:	Honolulu[c]	P	2	2	0	0	13	2
Idaho:	Idaho Falls[c]	P	7	5	0	0	0	6
Ill:	Chicago[c]	P	7	7	0	0	11	11
Ind:	Indianapolis[c]	P	NA	7	0	0	0	5
	Northeast	P	8	9	0	0	10	15
	Southeast	P	12	10	0	0	15	14
	Central	P	9	8	0	5	10	12
	Southwest	P	8	10	0	0	15	13
	Northwest	P	8	10	0	0	15	13
Iowa:	Des Moines[c]	P	NA	6	0	0	0	3
	Des Moines	P	9	7	0(5)	0	7(5)	11
	Iowa City	P	8	8	0	0	17	15
	Little Cedar	P	NS		NS		NS	
	Spencer	P	7	6	0	0	15	15
Kans:	Wichita[c]	P	NA	7	0	0	0	2
	Coffeyville	P	6	9	0	4	21	11
	Dodge City	P	5	7	0	0	10	5
	Falls City	P	5	3	0	3	10	9
	Hays	P	11	10	0	3	13	7
	Kansas City	P	7	6	6	5	10	14
	Topeka	P	10	10	0	3	10	11
	Wichita	P	7	11	0	1	13	10
Ky:	Louisville[c]	P	NA	9	0	0	14	4
La:	New Orleans[c]	P	17	14	0	0	31	20
Maine:	Portland[c]	P	NA	9	0	0	28	21
Md:	Baltimore[c]	P	NA	8	0	0	11	7
Mass:	Boston[c]	P	8	9	0	0	13	17
Mich:	Detroit[c]	P	NA	7	0	0	14	11
	Grand Rapids[c]	P	NA	9	0	0	0	13
	Bay City	P	6	6	≤0	≤0	20	14
	Charlevoix	P	11	10	≤0(2)	≤1	18(2)	15
	Detroit	P	6	7	≤0	≤0	17	8
	Grand Rapids	P	5	7	≤0	≤0	20	9
	Lansing	P	6	7	≤0(2)	≤0	18(2)	15
	Marquette	P	12	10	≤0(2)	≤0	32(2)	23
	Monroe	P	3	5	≤0(2)	≤0	0(2)	3
	South Haven	P	6	7	≤0(5)	≤0	15(5)	9
Minn:	Minneapolis[c]	P	NA	9	0	0	30	16
	Bemidji	P	8	8	0	0	22	21
	Duluth	P	21	17	0	0	43	28
	Fergus Falls	P	8	7	0	0	18	14
	Little Falls	P	20	16	0	0	53	27
	Mankato	P	5	6	0	0	19	11
	Minneapolis	P	12	12	0	0	22	24
	Rochester	P	NS	7	NS	0	NS	12
	Worthington	P	7	6	0	0	12	0

See footnotes at end of table.

Table 2. Concentrations of radionuclides in milk for August 1971 and 12-month period, September 1970 through August 1971—continued

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month avarege
UNITED STATES—continued								
Miss:	Jackson[c]	P	NA	12	0	0	15	9
Mo:	Kansas City[c]	P	NA	7	0	0	19	5
	St. Louis[c]	P	NA	6	0	0	19	6
Mont:	Helena[c]	P	NA	6	0	0	12	12
Nebr:	Omaha[c]	P	NA	6	0	0	13	4
Nev:	Las Vegas[c]	P	NA	2	0	0	0	1
N.H:	Manchester[c]	P	NA	9	0	0	19	21
N.J:	Trenton[c]	P	NA	9	0	0	14	11
N. Mex:	Albuquerque[c]	P	NA	3	0	0	0	0
N.Y:	Buffalo[c]	P	7	7	0	0	15	11
	New York City[c]	P	NA	9	0	0	15	16
	Syracuse[c]	P	NA	7	0	0	20	10
	Albany	P	6	7	0	0	0	0
	Buffalo	P	0	0	0	0	0	0
	Massena	P	8	8	0	0	25	24
	New York City	P	0	8	0	0	0	0
	Syracuse	P	7	4	0	0	0	0
N.C:	Charlotte[c]	P	NA	11	0	0	11	13
N. Dak:	Minot[c]	P	NA	10	0	0	22	9
Ohio:	Cincinnati[c]	P	NA	7	0	0	0	2
	Cleveland[c]	P	NA	8	0	0	0	10
Okla:	Oklahoma City[c]	P	NA	6	0	0	0	8
Oreg:	Portland[c]	P	7	5	0	0	11	5
	Baker	P	NA	2	0	0	0	6
	Coos Bay	P	NA	6	0	0	0	9
	Eugene	P	NA	3	0	0	0	3
	Medford	P	NA	1	0	0	0	5
	Portland composite	P	NA	6	0	0	0(2)	5
	Portland local	P	NA	4	0	0	10(2)	10
	Redmond	P	NA	3	0	0	0	2
	Tillamook	R	NA	7	0	0	25	16
Pa:	Philadelphia[c]	P	NA	8	0	0	15	9
	Pittsburgh[c]	P	NA	11	0	0	11	13
	Dauphin	P	NA	7	0	1	16	13
	Erie	P	NA	6	0	0	20	19
	Philadelphia	P	NA	8	0	0	16	15
	Pittsburgh	P	NA	11	0	1	0	17
R.I:	Providence[c]	P	NA	8	0	0	17	19
S.C:	Charleston[c]	P	9	9	0	0	20	15
S. Dak:	Rapid City[c]	P	NA	6	0	0	14	5
Tenn:	Chattanooga[c]	P	NA	9	0	0	15	9
	Memphis[c]	P	NA	7	0	0	14	9
	Chattanooga	P	NA	9	0	0	15	15
	Clinton	R	NA	9	0(2)	0	5(2)	16
	Fayetteville	P	NA	10	0(2)	0	6(2)	13
	Kingston	R	NA	9	0(2)	0	15(2)	18
	Knoxville	P	NA	6	0(2)	0	17(2)	13
	Lawrenceburg	R	NA		0(2)	0	10(2)	10
	Nashville	P	NA	6	0	0	12	13
	Pulaski	R	NA	9	0(2)	0	12(2)	6
Tex:	Austin[c]	P	NA	1	0	0	0	0
	Dallas[c]	P	NA	6	0	0	0	5
	Amarillo	R	NS	4	NS	0	NS	2
	Corpus Christi	R	5	4	0	0	0	0
	El Paso	R	2	3	0	0	0	0
	Fort Worth	R	NS	4	NS	0	NS	0
	Harlingen	R	NS	2	NS	0	NS	0
	Houston	R	NS	7	NS	0	NS	16
	Lubbock	R	4	3	0	0	0	0
	Midland	R	NS	2	NS	0	NS	0
	San Antonio	R	NS	4	NS	0	NS	0
	Texarkana	R	NS		NS	0	NS	
	Tyler	R	9	14	0	0	18	17
	Uvalde	R	NS		NS	0	NS	
	Wichita Falls	R	8	6	0	0	0	4
Utah:	Salt Lake City[c]	P	6	5	0	0	25	16
Vt:	Burlington[c]	P	NA	6	0	0	11	14
Va:	Norfolk[c]	P	NA	9	0	0	0	6
Wash:	Seattle[c]	P	NA	5	0	0	0	4
	Spokane[c]	P	NA	6	0	0	11	4
	Benton County	R	NS	1	NS	0	NS	2
	Franklin County	R	4	4	0	0	0	5
	Sandpoint, Idaho	R	15	13	0	0	37	22
	Skagit County	R	NA	9	0(2)	0	15(2)	18
W. Va:	Charleston[c]	P	NA	8	0	0	0	9
Wisc:	Milwaukee[c]	P	NA	6	0	0	0	11
Wyo:	Laramie[c]	P	NA	5	0	0	0	1
CANADA:								
Alberta:	Calgary	P	NA		(d)		18	19
	Edmonton	P	NA		(d)		30	23
British Columbia:	Vancouver	P	NA		(d)		37	24
Manitoba:	Winnipeg	P	NA		(d)		28	24

See footnotes at end of table.

Table 2. Concentrations of radionuclides in milk for August 1971 and 12-month period, September 1970 through August 1971—continued

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average
CANADA—continued								
New Brunswick:	Fredericton	P	NA		(d)		29	25
Newfoundland:	St. John's	P	NA		(d)		51	31
Nova Scotia:	Halifax	P	NA		(d)		48	24
Ontario:	Ottawa	P	NA		(d)		12	15
	Sault Ste. Marie	P	NA		(d)		44	33
	Thunder Bay	P	NA		(d)		18	26
	Toronto	P	NA		(d)		17	13
	Windsor	P	NA		(d)		10	11
Quebec:	Montreal	P	NA		(d)		14	18
	Quebec	P	NA		(d)		30	29
Saskatchewan:	Regina	P	NA		(d)		12	14
	Saskatoon	P	NA		(d)		18	18
CENTRAL AND SOUTH AMERICA:								
Colombia:	Bogota	P	0	1	0	0	0	0
Chile:	Santiago	P	0	0	0	0	12	2
Ecuador:	Guayaquil	P	0	0	0	0	0	0
Jamaica:	Mandeville	P	4	4	0	0	63	51
Venezuela:	Caracas	P	2	1	0	0	0	0
Canal Zone:	Cristobal[c]	P	NA	1	0	0	11	10
Puerto Rico:	San Juan[c]	P	NA	3	0	0	14	12
PMN network average[f]			8	7	0	0	11	9

[a] P, pasteurized milk.
R, raw milk.
[b] When an individual sampling result was equal to or less than the practical reporting level, a value of "0" was used for averaging. Monthly averages less than the practical reporting level reflect the fact that some but not all of the individual samples making up the average contained levels greater than the practical reporting level. When more than one analysis was made in a monthly period, the number of samples in the monthly average is given in parentheses.
[c] Pasteurized Milk Network station. All other sampling locations are part of the State or National network.
[d] Radionuclide analysis not routinely performed.
[e] The practical reporting levels for these networks differ from the general ones given in the text. Sampling results for the networks were equal to or less than the following practical reporting levels:
Iodine-131: Colorado—25 pCi/liter; Michigan—14 pCi/liter; Oregon—15 pCi/liter
Cesium-137: Colorado—25 pCi/liter; New York—20 pCi/liter; Oregon—15 pCi/liter
Strontium-90: New York—3 pCi/liter
[f] This entry gives the average radionuclide concentrations for the Pasteurized Milk Network stations denoted by footnote [c].
NA, no analysis.
NS, no sample collected.

for Colorado. This is reflected in the practical reporting level for the Colorado milk network.

Federal Radiation Council guidance applicable to milk surveillance

In order to place the U.S. data on radioactivity in milk presented in *Radiological Health Data and Reports* in perspective, a summary of the guidance provided by the Federal Radiation Council for specific environmental conditions was presented in the December 1970 issue of *Radiological Health Data and Reports.*

Data reporting format

Table 2 presents the integrated results of the international, national, and State networks discussed earlier. Column 1 lists all the stations which are routinely reported to *Radiological Health Data and Reports.* The relationship between the PMN stations and the State stations is shown in figure 2. The first column under each of the reported radionuclides gives the monthly average for the station and the number of samples analyzed in that month in parentheses. When an individual sampling result is equal to or below the practical reporting level for the radionuclide, a value of zero is used for averaging. Monthly averages are calculated using the above convention. Averages which are equal to or less than the practical reporting levels reflect the presence of radioactivity in some of the individual samples greater than the practical reporting level.

The second column under each of the radionuclides reported gives the 12-month average for the station as calculated from the preceding 12 monthly averages, giving each monthly average equal weight. Since the daily intake of radioactivity by exposed population groups,

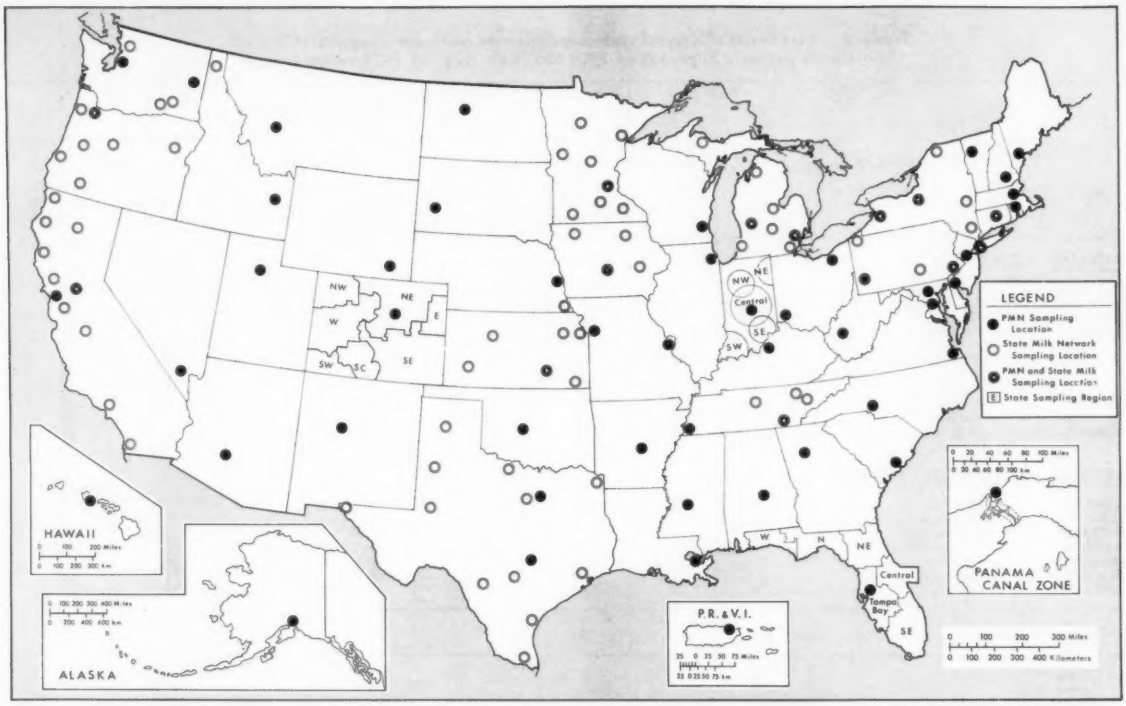

Figure 2. State and PMN milk sampling stations in the United States

averaged over a year, constitutes an appropriate criterion for the case where the FRC radiation protection guides apply, the 12-month average serves as a basis for comparison.

Discussion of current data

In table 2, surveillance results are given for strontium-90, iodine-131, and cesium-137 for August 1971 and the 12-month period, September 1970 to August 1971. Except where noted, the monthly average represents a single sample for the sampling station. Strontium-89 and barium-140 data have been omitted from table 2 since levels at the great majority of the stations for August 1971 were below the respective practical reporting levels. Table 3 gives monthly averages for those stations at which strontium-89 was detected.

Iodine-131 results are included in the table, even though they were generally below practical reporting levels. Because of the lower guide levels established by the Federal Radiation Council, levels in milk for this radionuclide are of particular public health interest.

Table 3. Strontium-89 in milk, August 1971

Sampling location		Radionuclide concentration (pCi/liter)
Calif:	Del Norte (State)	8
Kans:	Coffeyville (State)	7
	Kansas City (State)	8
N.Y:	New York City (State)	8
Chile:	Santiago (PAHO)	42
Ecuador:	Guayaquil (PAHO)	7
Jamaica:	Mandeville (PAHO)	7

In general, the practical reporting level for iodine-131 is numerically equal to the upper value of Range I (10 pCi/liter) of the FRC radiation protection guide.

Strontium-90 monthly averages ranged from 0 to 21 pCi/liter in the United States for August 1971, and the highest 12-month average

was 17 pCi/liter (Duluth, Minn.) representing 8.5 percent of the Federal Radiation Council radiation protection guide. Cesium-137 monthly averages ranged from 0 to 53 pCi/liter in the United States for August 1971, and the highest 12-month average was 68 pCi/liter (Southeast Florida), representing 1.9 percent of the value derived from the recommendations given in the Federal Radiation Council report. Of particular interest are the consistently higher cesium-137 levels that have been observed in Florida (*8*) and Jamaica.

Acknowledgment

Appreciation is expressed to the personnel of the following agencies who provide data for their milk surveillance network:

Bureau of Radiological Health
Division of Environmental Sanitation
California State Department of Health

Radiation Protection Division
Canadian Department of National Health and Welfare

Radiological Health Section
Division of Occupational and Radiological Health
Colorado Department of Health

Radiological Health Services
Division of Medical Services
Connecticut State Department of Health

Radiological and Occupational Health Section
Department of Health and Rehabilitative Services
State of Florida

Bureau of Environmental Sanitation
Division of Sanitary Engineering
Indiana State Board of Health

Division of Radiological Health
Environmental Engineering Services
Iowa State Department of Health

Radiation Control Section
Environmental Health Division
Kansas State Department of Health

Radiological Health Services
Division of Occupational Health
Michigan Department of Health

Radiation Control Section
Division of Environmental Health
State of Minnesota Department of Health

Bureau of Radiological Pollution Control
New York State Department of Environmental Conservation

Environmental Radiation Surveillance Program
Division of Sanitation and Engineering
Oregon State Board of Health

Radiological Health Section
Bureau of Environmental Health
Pennsylvania Department of Public Health

Radiological Health Services
Division of Preventable Diseases
Tennessee Department of Public Health

Division of Occupational Health
Environmental Health Services
Texas State Department of Health

Radiation Control Section
Division of Health
Washington Department of Social and Health Services

REFERENCES

(1) CAMPBELL, J. E., G. K. MURTHY, A. S. GOLDIN, H. B. ROBINSON, C. P. STRAUB, F. J. WEBER and K. H. LEWIS. The occurrence of strontium-90, iodine-131, and other radionuclides in milk, May 1957 through April 1958. Amer J Pub Health 49:225 (February 1959).
(2) U.S. ATOMIC ENERGY COMMISSION, DIVISION OF ISOTOPES DEVELOPMENT. Chart of the Nuclides, Tenth Edition revised to December 1968. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (1970)
(3) NATIONAL CENTER FOR RADIOLOGICAL HEALTH. Section I. Milk Surveillance. Radiol Health Data Rep 9:730-746 (December 1968).
(4) ROSENSTEIN, M. and A. S. GOLDIN. Statistical technics for quality control of environmental radioassay. Health Lab Sci 2:93 (April 1965).
(5) KNOWLES, F. Interlaboratory study of iodine-131, cesium-137, barium-140, strontium-89, and strontium-90 measurements in milk, May-July 1970, Technical experiment 70-MKAQ-1. Analytical Quality Control Service, Bureau of Radiological Health (September 1970).
(6) NEILL, R. H. and D. R. SNAVELY. State Health Department sampling criteria for surveillance of radioactivity in milk. Radiol Health Data Rep 8:621-627 (November 1967).
(7) ROBINSON, P. B. A comparison of results between the Public Health Service Raw Milk and Pasteurized Milk Networks for January 1964 through June 1966. Radiol Health Data Rep 9:475-488 (September 1968).
(8) PORTER, C. R., C. R. PHILLIPS, M. W. CARTER, and B. KAHN. The cause of relatively high cesium-137 concentrations in Tampa, Florida, milk. Radioecological Concentration Processes, Proceedings of an International Symposium held in Stockholm, April 25-29, 1966. Pergamon Press, New York, N.Y. (1966) pp. 95–101.

Food and Diet Surveillance

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuing basis. These estimates, along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and reported routinely include those listed below. These networks provide data useful for developing estimates of nationwide dietary intakes of radionuclides. Programs reported in *Radiological Health Data and Reports* are as follows:

Program	Period reported	Issue
California Diet Study	July–December 1970	November 1971
Carbon-14 and Tritium in Total Diet and Milk	January–June 1971	December 1971
Connecticut Standard Diet	January–December 1970	December 1970
Institutional Diet Samples	April–June 1971	November 1971
Strontium-90 in Tri-City Diets	January–December 1970	November 1971

Carbon-14 in Total Diet and Milk, January–June 1971

Environmental Protection Agency
Office of Radiation Programs

In July 1965, a program to determine the levels of carbon-14 and tritium in the total diet and milk in the United States was initiated. In December 1970, this program was transferred to the Office of Radiation Programs of the Environmental Protection Agency (EPA). Initially, monthly samples from each of the EPA Institutional Total Diet Sampling Network (ITDSN) and Pasteurized Milk Network (PMN) stations were composited and analyzed according to six arbitrarily selected regions: Northeast, South, Delta, Central, Southwest, and Northwest. Figure 1 shows the ITDSN and PMN sampling stations in each of the designated regions.

In January 1966, the program was modified to include selected stations in each of the previously mentioned regions plus Alaska and Hawaii. The nine geographically distributed sampling stations are: Palmer, Alaska; Honolulu, Hawaii; Idaho Falls, Idaho; Chicago, Ill; New Orleans, La; Boston, Mass; Portland, Oreg; and Charleston, S.C. Los Angeles, Calif. is not a PMN station, but a special milk sample is collected for purposes of comparison with the routine ITDSN sample.

A 1-liter milk sample and a 2-kilogram food sample are sent to the PHS Northeastern Radiological Health Laboratory for analysis. The milk and total diet samples analyzed represent the samples collected for that month.

The carbon-14 analyses are performed semiannually. The tritium analyses were discontinued in July 1969 because the results were only slightly above the limit of detectability and were less than 1 percent of the maximum permissible concentration for milk and food consumed by the general population.

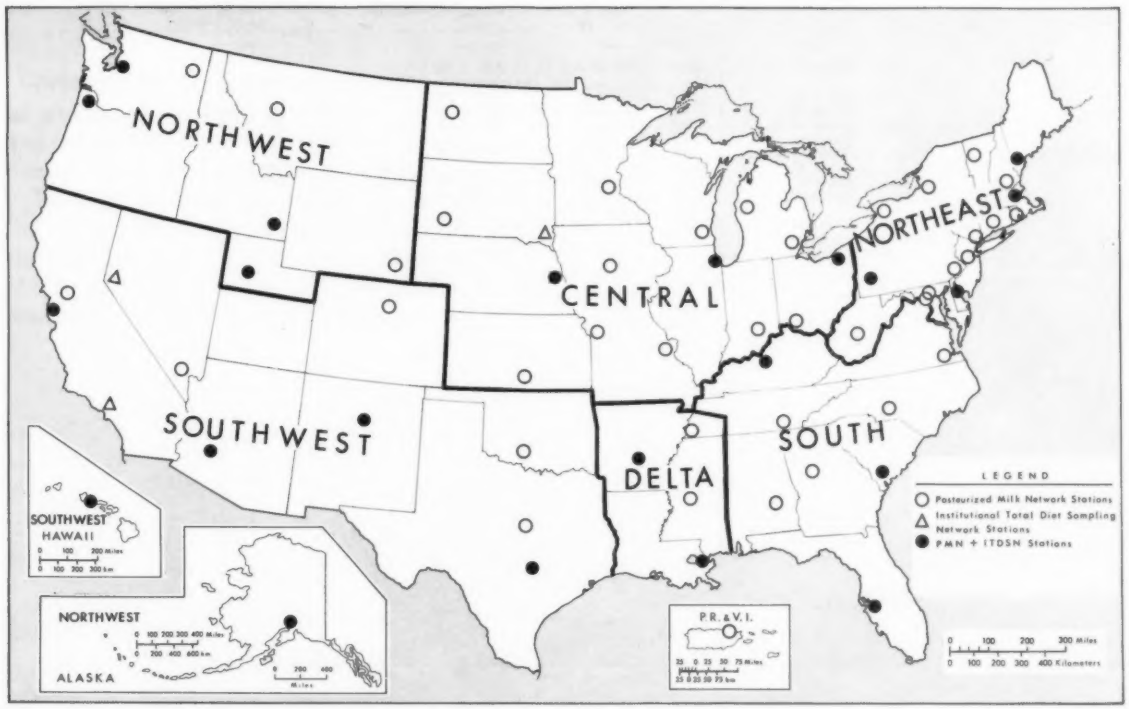

Figure 1. ITDSN and PMN sampling stations

Analytical procedures

The carbon-14 content is determined by combustion of the milk or food sample and collection and purification of the evolved carbon dioxide. The carbon dioxide is then converted to methane and counted in a gas-proportional counter (*1*).

Results and discussion

The carbon-14 concentration in food and milk was measured as dpm of carbon-14 per gram of carbon and converted to pCi/kg or pCi/liter by using the percent carbon in the sample. The carbon content in food ranged from 8.9 to 11.1 percent with an average of 10.4 percent, and the carbon content in milk ranged from 4.5 to 7.4 percent with an average of 5.4 percent. Table 1 shows the dpm per gram of carbon and the carbon-14 concentrations in total diet and milk for January–June 1971.

Other coverage in *Radiological Health Data and Reports:*

Period	Issue
July 1965–December 1968	November 1969
January 1969–June 1970	January 1971
July–December 1970	May 1971

REFERENCE

(*1*) DROBINSKI, J. C. JR., D. P. LAGATTA, A. S. GOLDIN, and J. G. TERRILL. Analyses of environmental samples for carbon-14 and tritium. Health Phys 11:385–395 (May 1965).

Table 1. Carbon-14 in total diet and milk, January–June 1971

Location		Date collected	Total diet		Milk	
			dpm/g C ± 2σ	pCi/kg ± 2σ	dpm/g C ± 2σ	pCi/liter ± 2σ
Alaska:	Palmer	April	18.02 ± 0.33	840 ± 30		
		May			15.39 ± 0.31	390 ± 10
Calif:	Los Angeles	April	16.97 ± .31	790 ± 30	17.36 ± .36	440 ± 10
Hawaii:	Honolulu	April	17.02 ± .28	790 ± 30	NS	NS
Idaho:	Idaho Falls	April	18.48 ± .36	860 ± 30	18.37 ± .46	460 ± 10
Ill:	Chicago	April			16.00 ± .30	400 ± 10
La:	New Orleans	April	17.08 ± .30	800 ± 30		
		May			17.88 ± .40	450 ± 10
Mass:	Boston	April	15.92 ± .38	740 ± 40	15.07 ± .30	380 ± 10
Oreg:	Portland	April	16.85 ± .31	790 ± 30		
		May			17.96 ± .30	450 ± 10
S.C:	Charleston	April	17.50 ± .36	820 ± 30	17.17 ± .44	430 ± 10
Average			17.23	800	16.90	430

NS, no sample.

Estimated Daily Intake of Radionuclides in Connecticut Standard Diet January–December 1970

Connecticut State Department of Health

The Connecticut State Department of Health has been analyzing a standard diet on a monthly basis since March 1963. Analysis are made for strontium-89, strontium-90, and gamma-ray emitters.

The standard diet was selected to represent the food intake of an 18-year old boy for 1 day (table 1). The total weight of the complete blended diet, averaging 3 kilograms, included milk and dairy products. When raw fruit or vegetables were sampled, they were washed before blending.

Table 1. Foods included in standard diet

Bread, white—8 slices	Ice cream—½ pint
Butter, ½ stick	Lettuce, washed—4,5 leaves
Carrots, scraped—½ cup	Milk—3 cups
Celery, washed and trimmed—3 stalks	Oatmeal—uncooked—43 grams
Cookies—4	Orange—1
Cottage cheese—¾ cup	Peanut butter—2½ tablespoons
Cupcakes—2	Pears, canned—2 halves with juice
Egg—1	Potatoes, washed, not peeled—2
Green beans, washed—½ cup	Sugar—5 tablespoons
Ham—85 grams	Tomato juice—113 grams
Hamburger—227 grams	Tuna fish, drained—43 grams

Cesium-137 concentrations were determined by gamma-ray spectrometry (*1*). Strontium-89 and strontium-90 concentrations were determined by chemical separation techniques (*1*).

Table 2 presents the analytical results for the Connecticut standard diet from January through December 1970. Results representative of the total daily intake for the radionuclides observed are presented in table 3.

Table 2. Radionuclide concentrations in Connecticut standard diet,[a] January-December 1970

Month (1970)	Potassium (g/kg)	Strontium-90 (pCi/kg)	Cesium-137 (pCi/kg)
January	2.2	5.8	10
February	2.0	5.3	5
March	1.9	6.3	5
April	1.9	5.4	10
May	2.2	8.1	10
June	2.0	5.7	20
July	1.9	8.4	10
August	2.5	8.0	20
September	2.2	8.2	10
October	NS	NS	NS
November	2.1	NA	10
December	2.2	8.3	13

[a] All strontium-89 values were below the detectable level for this period.
NA, no analysis.
NS, no sample.

In order to evaluate general trends, the strontium-90 and cesium-137 daily intakes are plotted as a function of time in figures 1 and 2.

Table 3. Daily radionuclide intakes in Connecticut standard diet,[a] January-December 1970

Month (1970)	Potassium (g/day)	Strontium-90 (pCi/day)	Cesium-137 (pCi/day)
January	7.1	18.6	40
February	6.8	17.7	20
March	5.8	19.3	20
April	6.4	18.0	40
May	6.8	25.6	30
June	7.6	19.6	60
July	5.9	25.6	30
August	8.7	28.2	70
September	7.5	28.1	50
October	NS	NS	NS
November	6.7	NA	40
December	7.3	27.0	40

[a] All strontium-89 values were below the detectable level limit for this period.
NA, no analysis.
NS, no sample.

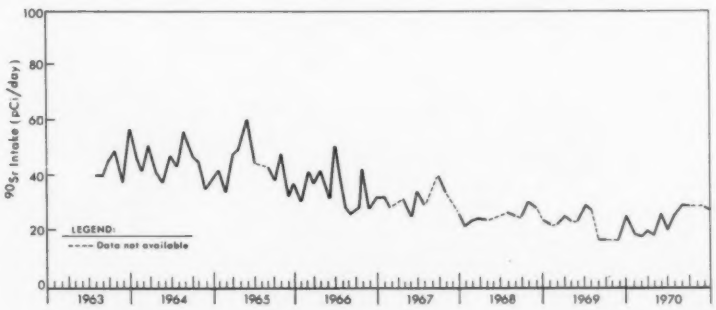

Figure 1. Strontium–90 intake in Connecticut standard diet 1963–December 1970

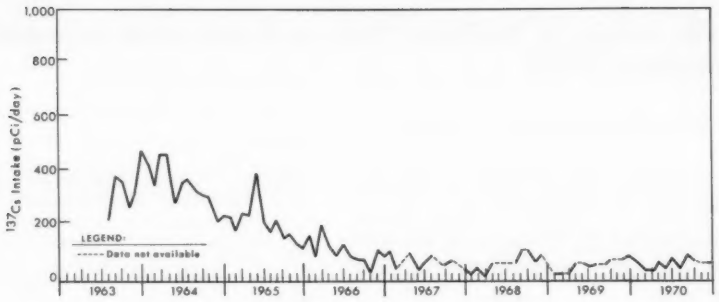

Figure 2. Cesium–137 intake in Connecticut standard diet 1963–December 1970

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–December 1969	December 1970

REFERENCE

(*1*) CONNECTICUT STATE DEPARTMENT OF HEALTH. Estimated daily intake of radionuclides in Connecticut standard diet, March 1963–December 1964. Radiol Health Data 6:381–382 (July 1965).

SECTION II. WATER

The Environmental Protection Agency and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (*1*). These standards, based on consideration of Federal Radiation Council (FRC) recommendations (*2-4*), set the limits for approval of a drinking water supply containing radium-226 and strontium-90 at 3 pCi/liter and 10 pCi/liter, respectively. Higher concentrations may be acceptable if the total intake of radioactivity from all sources remains within the guides recommended by FRC for control action. In the known absence [1] of strontium-90 and alpha-particle emitters, the limit is 1,000 pCi/liter gross beta radioactivity, except when additional analysis indicates that concentrations of radionuclides are not likely to cause exposures greater than the limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water sampling activities reported in *Radiological Health Data and Reports* are listed below.

[1] Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha-particle emitters and strontium-90, respectively.

Water sampling program	Period reported	Issue
California	January–December 1969	October 1971
Gross Radioactivity in Surface Waters of the United States	March 1971	November 1971
Interstate Carrier Drinking Water	1970	July 1971
Kansas	January–June 1970	November 1971
Minnesota	January–June 1970	November 1971
North Carolina	January–December 1967	May 1969
New York	July 1969–June 1970	September 1971
Radiostrontium in Tap Water, *HASL*	January–June 1970	April 1971
Tritium in Community Water Supplies	1969	December 1970
Tritium Surveillance System	April–June 1971	November 1971
Washington	July 1968–June 1969	February 1971

REFERENCES

(*1*) U.S. PUBLIC HEALTH SERVICE. Drinking water standards, revised 1962, PHS Publication No. 956. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (March 1963).

(*2*) FEDERAL RADIATION COUNCIL. Radiation Protection Guidance for Federal Agencies. Memorandum for the President, September 1961. Reprint from the Federal Register of September 26, 1961.

(*3*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1960).

(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

Radioactivity in Kansas Surface Waters, January–December 1970

Radiation Control Section
Kansas State Department of Health

Monitoring the levels of radioactivity in the surface waters of Kansas is conducted by the Kansas State Department of Health, Radiation Control Section, in cooperation with the Radiological Laboratory and Water Data Analysis Section. This surveillance program is important because of both the present and future potential use of Kansas surface waters for domestic, recreational, and industrial purposes.

Liter samples are collected every month at each location shown in figure 1. These samples are analyzed for alpha and beta radioactivity. Radioactivity in these waters consists of the natural radioactivity picked up by flowing streams, radioactivity from sewage discharge into the streams, and some contribution by industrial waste. The final contributing factor to radioactivity content is fallout, particularly over large expanses of open water, such as reservoirs and lakes.

Analytical procedures

Radioactivity analyses are performed by the Kansas Radiological Health Laboratory. Measurements of gross alpha and gross alpha-plus-beta radioactivity in total solids are made with a windowless gas-flow proportional counter. Each sample is evaporated in an aluminum planchet, dried at 250° C. and then counted. Specific radionuclide analyses are determined by gamma spectroscopy or chemical separation.

Discussion

Table 1 shows the gross alpha and gross alpha-plus-beta radioactivity in the total solids in Kansas surface waters from January through December 1970. These waters are used for domestic, industrial, and recreational purposes. Recently there has been much discussion as to establishing a nuclear waste repository in Kansas. If the decision is made to establish such a repository, the entire environmental surveillance program including surface water will be increased around the proposed site.

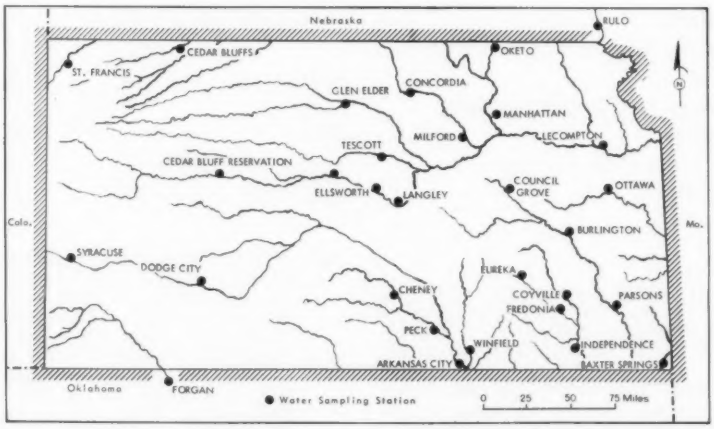

Figure 1. Kansas surface water sampling stations

Table 1. Gross radioactivity in Kansas surface waters, January–June 1970

River	Sampling station	Radioactivity concentration (pCi/liter)											
		January		February		March		April		May		June	
		Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta
Arkansas:	Arkansas City	*16	14	ND	*31	*3	ND	*11	*21	*3	72	*6	*22
	Dodge City	*18	ND	*12	0	*15	ND	*1	86	*14	20	*16	*33
	Syracuse	36	ND	NS	NS	39	13	NS	NS	*4	71	35	14
Beaver Creek:	Cedar Bluffs	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	ND	33
Big Blue:	Manhattan	NS	NS	ND	*29	ND	*28	ND	*7	5	10	ND	*21
	Oketo	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Cimarron:	Forgan, Okla	*8	*3.3	NS	NS	NS	NS	*11	26	NS	NS	*2	ND
Fall:	Eureka	*3	*8	ND	ND	*2	*15	*4	*9	*3	76	ND	7
	Fredonia	ND	*16	*5	*27	ND	*16	2	26	*4	*32	ND	1
Kansas:	Lecompton	10	*22	*1	*9	NS	NS	*7	*40	*6	*22	*5	*32
Marais des Cygnes:	Ottawa	*2	ND	*2	*12	*5	ND	1	5	*3	*29	*2	*10
Missouri:	Rulo, Nebr	NS	NS	NS	NS	NS	NS	*3	4	*6	80	ND	ND
Neosho:	Burlington	ND	43	ND	*6	NS	NS	1	*29	NS	NS	NS	NS
	Council Grove	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	Parsons	ND	*19	*2	*16	*2	*23	2	*23	*2	*13	1	*20
Ninnescah:	Cheney	ND	*25	ND	*14	NS	NS	2	10	NS	NS	NS	NS
	Peck	NS	NS	NS	NS	NS	NS	*5	66	ND	2	1	*8
Republican:	Concordia	*3	29	*2	32	*1	*24	*4	37	1	*32	ND	*9
	Milford	*9	*25	*3	*23	NS	NS	*1	33	ND	8	8	37
	St. Francis	NS	NS	*7	*4	NS	NS	NS	NS	11	ND	NS	NS
Saline:	Tescott	*8	*35	*3	*4	*7	*30	*10	*61	*4	*64	*8	*16
	Wilson	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Smoky Hill:	Cedar Bluff	NS	NS	*12	*37	NS	NS	*6	43	*11	49	NS	NS
	Ellsworth	*3	*3	ND	21	*5	*29	*9	39	*8	68	4	28
	Langley	*2	*26	ND	*28	*5	*34	1	34	*3	33	*12	*18
Solomon:	Glenn Elder	*1	*20	*7	*33	*8	*16	1	51	*8	61	*3	37
Spring:	Baxter Springs	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Verdigris:	Coyville	*2	*33	*2	*14	ND	*23	*4	37	1.4	*26	NS	NS
	Independence	*4	*20	ND	*11	*4	*3	*4	50	ND	44	1	*10
Walnut:	Winfield	*1	*14	*7	ND	ND	*4	*2	30	2	*20	ND	*10

* When the counting rate of the sample is not equal to at least twice the 95-percent error, the value reported is not statistically significant but is the best available estimate.
ND, nondetectable.
NS, no sample.

Tabel 1. Gross radioactivity in Kansas surface waters, July–December 1970

River	Sampling station	Radioactivity concentration (pCi/liter)											
		July		August		September		October		November		December	
		Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta
Arkansas:	Arkansas City	*14	3	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	Dodge City	*16	9	27	ND	*11	ND	46	*11	NS	NS	*51	15
	Syracuse	NS	NS	*39	10	*21	*47	12	*48	*11	*12	65	ND
Beaver Creek:	Cedar Bluffs	NS	NS	*4	6	NS	NS	NS	NS	NS	NS	NS	NS
Big Blue:	Manhattan	1	*16	ND	5	*5	*17	*4	ND	*5	ND	NS	NS
	Oketo	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Cimarron:	Forgan, Okla	NS	NS	NS	NS	NS	NS	*19	ND	*7	ND	NS	NS
Fall:	Eureka	*4	*21	4	9	NS	NS	NS	NS	NS	NS	NS	NS
	Fredonia	ND	1	*4	2	ND	ND	ND	4	2	*19	ND	6
Kansas:	Lecompton	*8	ND	3	ND	ND	12	*2	*11	24	4	4	ND
Marais des Cygnes:	Ottawa	*6	7	1	*10	2	*12	2	ND	4	ND	2	2
Missouri:	Rulo, Nebr	1	ND	*4	ND	*7	*9	1	23	NS	NS	NS	NS
Neosho:	Burlington	NS	NS	NS	NS	NS	NS	*3	*8	NS	NS	*4	*10
	Council Grove	NS	NS	NS	NS	NS	NS	*4	*15	NS	NS	NS	NS
	Parson	NS	NS	*3	ND	*5	ND	2	6	*2	*18	*2	ND
Ninnescah:	Cheney	*7	27	*4	*14	ND	*9	*2	*4	3	1	1	ND
	Peck	ND	3	2	*11	NS	NS	2	4	ND	ND	ND	ND
Republican:	Concordia	*13	38	1	*16	*4	*13	*8	*3	*7	4	*8	*15
	Milford	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	St. Francis	NS	NS	NS	NS	NS	NS	14	*13	NS	NS	15	*17
Saline:	Tescott	3	*42	ND	*14	ND	*17	*9	*13	1	*13	*9	*13
	Wilson	NS	NS	NS	NS	NS	NS	*6	*25	NS	NS	NS	NS
Smoky Hill:	Cedar Bluff	NS	NS	*17	26	*7	44	NS	NS	NS	NS	*13	42
	Ellsworth	15	66	ND	3	7	ND	4	ND	6	ND	*7	ND
	Langley	NS	NS	*8	*12	2	ND	*11	*20	ND	*8	NS	NS
Solomon:	Glenn Elder	*6	24	1	27	*6	*19	*5	28	*4	39	8	19
Spring:	Baxter Springs	NS	NS	1	ND	*2	ND	*2	6	2	1	NS	NS
Verdigris:	Coyville	ND	*16	1	21	*4	ND	ND	25	1	9	2	14
	Independence	ND	6	2	ND	1	3	ND	*16	1	ND	*5	*6
Walnut:	Winfield	NS	NS	ND	6	2	ND	ND	17	23	1	NS	NS

* When the counting rate of the sample is not equal to at least twice the 95-percent error, the value reported is not statistically significant but is the best available estimate.
ND, nondetectable.
NS, no sample.

SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product radioactivity. To date, this surveillance has been confined chiefly to gross beta radioanalysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the Environmental Protection Agency, the Canadian Department of National Health and Welfare, the Mexican Commission of Nuclear Energy, and the Pan American Health Organization.

In addition to those programs presented in this issue, the following programs were previously covered in *Radiological Health Data and Reports:*

Network	Period	Issue
Fallout in the United States and Other Areas, *HASL*	July–December 1968 and January–December 1969	January 1971
Plutonium in Airborne Particulates	January–March 1971	November 1971
Surface Air Sampling Program 80th Meridian Network, HASL	January–December 1968	April 1971
Mexican Air Monitoring Program	August–December 1970 and January 1971	October 1971

1. Radiation Alert Network August 1971

Division of Atmospheric Surveillance
Environmental Protection Agency

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Alert Network (RAN) which regularly gathers samples at 70 locations distributed throughout the country (figure 1). Most of these stations are operated by State Health Department personnel.

The station operators perform "field estimates" on the airborne particulate samples at 5 hours after collection, when most of the radon daughter products have decayed, and at 29 hours after collection, when most of the thoron daughter products have decayed. They also perform field estimates on dried precipitation samples and report all results to appropriate Environmental Protection Agency officials by mail or telephone depending on levels found. A compilation of the daily field estimates is available upon request from the Air Quality Information Systems Branch, Division of Atmospheric Surveillance, EPA, Research Triangle Park, North Carolina 27711. A detailed description of the sampling and analytical procedures was presented in the March 1968 issue of *Radiological Health Data and Reports.*

Table 1 presents the monthly average gross beta radioactivity in surface air particulates and deposition by precipitation, as measured by the field estimate technique, during August 1971.

All field estimates reported were within normal limits for the reporting station.

Figure 1. Radiation Alert Network sampling stations

Table 1. Gross beta radioactivity in surface air and precipitation, August 1971

Station location		Number of samples	Gross beta radioactivity (5-hour field estimate) (pCi/m³)			Number of samples	Total depth (mm)	Precipitation		
			Maximum	Minimum	Average[a]			Field estimation of deposition		
								Number of samples	Depth (mm)	Total deposition (mCi/m²)
Ala:	Montgomery	19	4	0	1	4	171	4	171	28
Alaska:	Anchorage	1	0	0	0	0				
	Attu Island	31	1	0	0	0				
	Fairbanks	18	1	0	0	7	58	7	58	16
	Juneau	0				0				
	Kodiak	0				0				
	Nome	0				0				
	Point Barrow	0				0				
Ariz:	Phoenix	13	4	1	2	0				
Ark:	Little Rock	11	2	0	0	0				
Calif:	Berkeley	17	1	0	0	0				
	Los Angeles	16	2	0	1	0				
C.Z:	Ancon	14	0	0	0	0				
Colo:	Denver	17	6	1	2	2	17	(b)		
Conn:	Hartford	17	1	0	0	7	67	7	67	0
Del:	Dover	19	1	0	1	0				
D.C:	Washington	21	1	0	0	0				
Fla:	Jacksonville	17	1	0	0	6	98	5	59	9
	Miami	17	0	0	0	9	144	9	144	0
Ga:	Atlanta	22	2	1	1	0				
Guam:	Agana	0				0				
Hawaii:	Honolulu	16	1	0	0	0				
Idaho:	Boise	17	4	0	2	0				
Ill:	Springfield	1	2	2	2	0				
Ind:	Indianapolis	15	2	0	1	0				
Iowa:	Iowa City	15	4	1	2	3	12	3	12	0
Kans:	Topeka	18	6	1	3	1	2	1	2	0
Ky:	Frankfort	0				0				
La:	New Orleans	14	1	0	0	10	141	(b)		
Maine:	Augusta	16	2	0	1	6	100	6	100	0
Md:	Baltimore	19	3	0	1	6	60	6	60	0
Mass:	Lawrence	17	2	0	1	4	115	4	115	0
	Winchester	18	3	0	1	4	87	4	87	0
Mich:	Lansing	18	3	0	1	8	28	8	28	4
Minn:	Minneapolis	18	3	0	1	3	29	3	29	5
Miss:	Jackson	13	7	0	2	1	22	1	22	2
Mo:	Jefferson City	18	7	1	2	0				
Mont:	Helena	18	5	1	2	3	22	3	22	0
Nebr:	Lincoln	18	10	0	5	3	16	3	16	3
Nev:	Las Vegas	16	3	1	1	0				
N.H:	Concord	0				0				
N.J:	Trenton	19	3	0	1	6	285	6	285	2
N. Mex:	Santa Fe	14	3	0	1	1	2	1	2	0
N.Y:	Albany	15	2	0	1	0				
	Buffalo	15	4	0	1	0				
	New York City	0				0				
N.C:	Gastonia	11	16	1	4	3	22	(b)		
N. Dak:	Bismarck	18	3	1	2	0				
Ohio:	Cincinnati	0				0				
	Columbus	3	1	1	1	0				
	Painesville	15	4	1	2	5	31	5	31	5
Okla:	Oklahoma City	0				0				
	Ponca City	16	5	0	2	4	92	4	92	0
Oreg:	Portland	14	1	0	0	2	7	2	7	1
Pa:	Harrisburg	18	3	0	1	0				
P.R:	San Juan	0				0				
R.I:	Providence	12	3	0	1	5	80	5	80	0
S.C:	Columbia	11	1	0	1	4	110	4	110	0
S. Dak:	Pierre	16	7	1	2	0				
Tenn:	Nashville	14	2	0	1	5	79	5	79	0
Tex:	Austin	1	1	1	1	1	47	(b)		
	El Paso	11	4	0	1	0				
Utah:	Salt Lake City	25	3	0	1	3	4	3	4	1
Vt:	Barre	16	5	1	2	5	103	5	103	13
Va:	Richmond	19	2	0	1	4	63	4	63	15
Wash:	Seattle	8	0	0	0	1	8	(b)		
	Spokane	14	2	0	1	0				
W. Va:	Charleston	18	3	0	1	6	56	6	56	4
Wisc:	Madison	17	2	0	1	4	80	4	80	9
Wyo:	Cheyenne	19	10	1	4	2	12	2	12	3
Network summary		914	16	0	1	148	76	4	67	4

[a] The monthly average is calculated by weighting the field estimates of individual air samples with length of sampling period.
[b] This station is part of the tritium surveillance system. No gross beta measurements are done.

2. Canadian Air and Precipitation Monitoring Program,[1] August 1971

Radiation Protection Division
Department of National Health and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 3), where the sampling equipment is operated by personnel from the Meteorological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*1-5*).

A summary of the sampling procedures and methods of analysis was presented in the May 1969 issue of *Radiological Health Data and Reports.*

[1] Prepared from information and data obtained from the Canadian Department of National Health and Welfare, Ottawa, Canada.

Surface air and precipitation data for August 1971 are presented in table 2.

Table 2. Canadian gross beta radioactivity in surface air and precipitation, August 1971

Station	Number of samples	Air surveillance, gross beta radioactivity (pCi/m³)			Precipitation measurements	
		Maximum	Minimum	Average	Average concentration (pCi/liter)	Total deposition (nCi/m²)
Calgary	51	0.3	0.2	0.2	NA	NA
Coral Harbour	5	.5	.1	.1	189	4.5
Edmonton	5	.3	.1	.2	102	1.2
Ft. Churchill	5	.2	.1	.1	119	4.4
Fredericton	5	.3	.1	.2	82	5.1
Goose Bay	5	.1	.1	.1	57	8.0
Halifax	5	.2	.1	.1	17	5.4
Inuvik	5	.1	.1	.1	103	4.8
Montreal	5	.2	.1	.1	42	4.3
Moosonee	5	.2	.1	.1	144	8.2
Ottawa	5	.3	.2	.2	42	5.2
Quebec	5	.3	.1	.2	41	8.7
Regina	5	.4	.1	.2	219	1.9
Resolute	5	.2	.1	.1	34	1.8
St. John's, Nfld.	5	.3	.1	.1	17	2.5
Saskatoon	5	.3	.1	.2	85	1.4
Sault Ste. Marie	5	.2	.1	.2	110	9.2
Thunder Bay	5	.2	.1	.1	130	5.2
Toronto	5	.3	.1	.2	85	7.7
Vancouver	5	.2	.1	.1	124	3.8
Whitehorse	5	.3	.1	.1	NA	NA
Windsor	5	.3	.1	.2	45	4.0
Winnipeg	5	.2	.1	.1	57	1.0
Yellowknife	5	.1	.0	.1	82	5.0
Network summary	146	0.5	0.0	0.1	87	4.7

NA, no analysis.

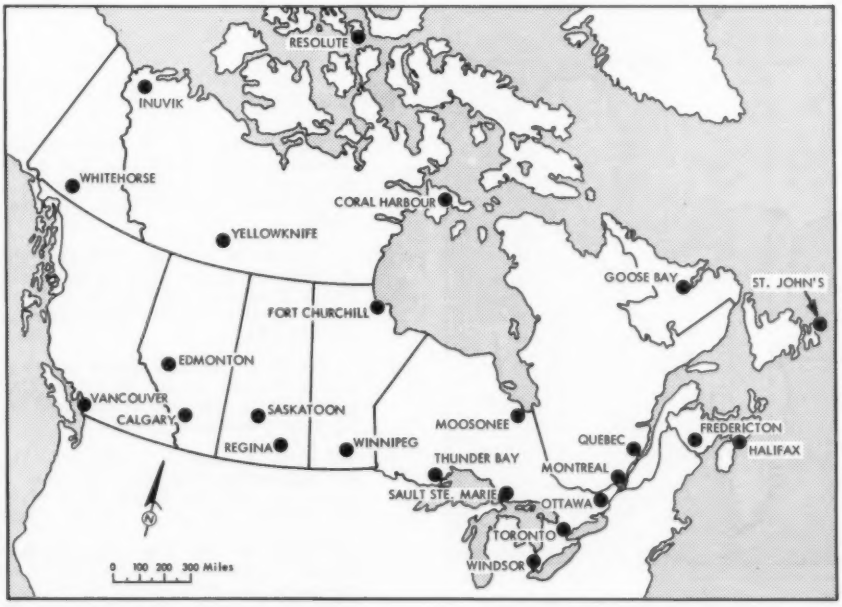

Figure 2. Canadian air and precipitation monitoring program

3. Pan American Air Sampling Program August 1971

Pan American Health Organization and Environmental Protection Agency

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the Environmental Protection Agency (EPA) to assist PAHO-member countries in developing radiological health programs.

The air sampling station locations are shown in figure 3. Analytical techniques were described in the March 1968 issue of *Radiological Health Data and Reports*. The August 1971 air monitoring results from the participating countries are given in table 3.

Table 3. Summary of gross beta radioactivity in Pan American surface air, August 1971

Station location		Number of samples	Gross beta radioactivity (pCi/m³)		
			Maximum	Minimum	Average[a]
Argentina:	Buenos Aires	0			
Bolivia:	La Paz	9	3.02	0.13	0.74
Chile:	Santiago	30	1.95	.09	.69
Colombia:	Bogota	18	.49	.00	.09
Ecuador:	Cuenca	10	1.69	.04	.47
	Guayaquil	17	1.76	.11	.52
	Quito	15	2.39	.01	.41
Guyana:	Georgetown	5	.13	.02	.07
Jamaica:	Kingston	0			
Peru:	Lima	23	1.96	.05	.58
Venezuela:	Caracas	18	.27	.04	.17
West Indies:	Trinidad	6	.56	.06	.36
Pan American summary		151	3.02	0.01	0.45

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values less than 0.005 pCi/m³ are reported and used in averaging as 0.00 pCi/m³.

Figure 3. Pan American Air Sampling Program stations

REFERENCES

(*1*) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report of 1959 on the Radioactive Fallout Study Program, CNHW-RP-3. Department of National Health and Welfare, Ottawa, Canada (May 1960).

(*2*) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report for 1960 on the Radioactive Fallout Study Program, CNHW-RP-4. Department of National Health and Welfare, Ottawa, Canada (December 1961).

(*3*) MAR, P. G. Annual report for 1961 on the Radioactive Fallout Study Program, CNHW-RP-5. Department of National Health and Welfare, Ottawa, Canada (December 1962).

(*4*) BEALE, J. and J. GORDON. The operation of the Radiation Protection Division Air Monitoring Program, RPD-11. Department of National Health and Welfare, Ottawa, Canada (July 1962).

(*5*) BOOTH, A. H. The calculation of permissible levels of fallout in air and water and their use in assessing the significance of 1961 levels in Canada, RPD-21. Department of National Health and Welfare, Ottawa, Canada (August 1962).

Fallout in the United States and Other Areas,[1] January–December 1970

Health and Safety Laboratory
Atomic Energy Commission

Monthly fallout deposition rates for strontium-90 are determined by the Health and Safety Laboratory (HASL) for 35 sites in the United States and 90 locations in other countries. HASL data from all the active United States stations and other selected points in the Western Hemisphere (figure 1) covering the period from January–December 1970 are summarized in tables 1 through 4. All the stations of the 80th Meridian Network are represented.

Methods of collection

Two methods of fallout collection are employed by HASL. In the first, precipitation and dry fallout are collected for a period of 1 month in a stainless steel pot with an exposed area of 0.076 m^2. At the end of the collection period, the contents are transferred, by careful scrubbing with a rubber spatula, to a polyethylene sample bottle which is then shipped to the laboratory for analysis.

The second method involves the use of a polyethylene funnel, with an exposed area of 0.072 m^2, attached to an ion exchange column. After a 1-month collection, the inside of the funnel is wiped with a tissue, and the tissue is inserted in the end of the column, which is then sealed and sent to HASL for analysis. It has been shown that at the 95-percent confidence level there was no significant difference in the strontium-90 measurements obtained from samples collected by the two methods (*1*).

[1] The data in this article were taken from "Fallout Program Quarterly Summary Report," HASL-243:A-1 to A-289 (July 1, 1971).

Table 1. Strontium-90 fallout in the United States, HASL, January–June 1970

Sampling location		Type of collection	Deposition (nCi/m²)					
			Jan	Feb	Mar	Apr	May	June
Ala:	Birmingham	pot	0.04	0.09	0.17	0.22	0.10	0.12
Alaska:	Anchorage	column	0.1	.01	[a]	.01	[b]	.16
	Barrow	column	[b]	[a]	[a]	[b]	[b]	[b]
	Cold Bay	column	.01	.04	.05	.07	.08	.18
	Fairbanks	column	[a]	.01	.01	[a]	.10	.16
	Juneau	column	.02	.04	.12	.11	.17	.17
	Nome	column	[a]	.01	[a]	[a]	.01	[b]
Calif:	W. Los Angeles	pot	.01	.03	.03	.01	[a]	.01
	San Francisco	column	.02	.03	.02	.01	.01	.02
Colo:	Denver	column	[a]	.02	.01	.02	.20	.20
Fla:	Coral Gables	pot	.05	.04	.04	.01	.46	.26
	Miami	column	.03	.01	.05	.03	.31	.17
Hawaii:	Honolulu	pot	.02	.02	.04	.24	.12	[c].13
	Lihue	column	.04	[a]	.04	.06	[b]	.17
	Mauna Loa	column	[a]	.01	[a]	.11	.04	[a]
Ill:	Argonne	pot	.02	.04	.06	.24	.13	.38
La:	New Orleans	column	.04	.02	.13	.01	.17	.13
Minn:	International Falls	column	[b]	.01	.02	.08	.33	.08
Mo:	Columbia	column	.01	.02	.10	.17	.74	.34
Mont:	Helena	column	.01	[a]	.03	.03	.19	.24
N.Y:	New York City	pot	.01	.10	.18	.13	.24	.25
N. Dak:	Williston	column	.02	[a]	.01	.09	.25	.24
Ohio:	Wooster	pot	.01	.01	.03	.10	.30	.52
Okla:	Tulsa	pot	.02	.14	.22	.18	.29	.24
Oreg:	Medford	column	.06	.03	.03	.17	.02	.13
S.C:	Columbia	column	.04	.02	.15	.05	[c].20	[c].21
S. Dak:	Vermillion	pot	.01	.02	.17	.25	.28	.47
Tex:	Dallas	column	[a]	.06	.16	.19	.18	.06
	El Paso	column	[a]	.02	.03	.01	.10	.04
	Houston	column	.04	.04	.22	.12	.43	.04
Utah:	Salt Lake City	pot	.05	.09	.19	.12	.25	.44
Va:	Sterling	column	.01	.05	.16	.19	.17	.21
Wash:	Forks	column	.09	[a]	.17	.46	.10	.10
Wisc:	Green Bay	column	.02	[a]	.03	.08	.42	.13

[a] Zero or trace.
[b] Data not available.
[c] Proportioned from originally consolidated data.

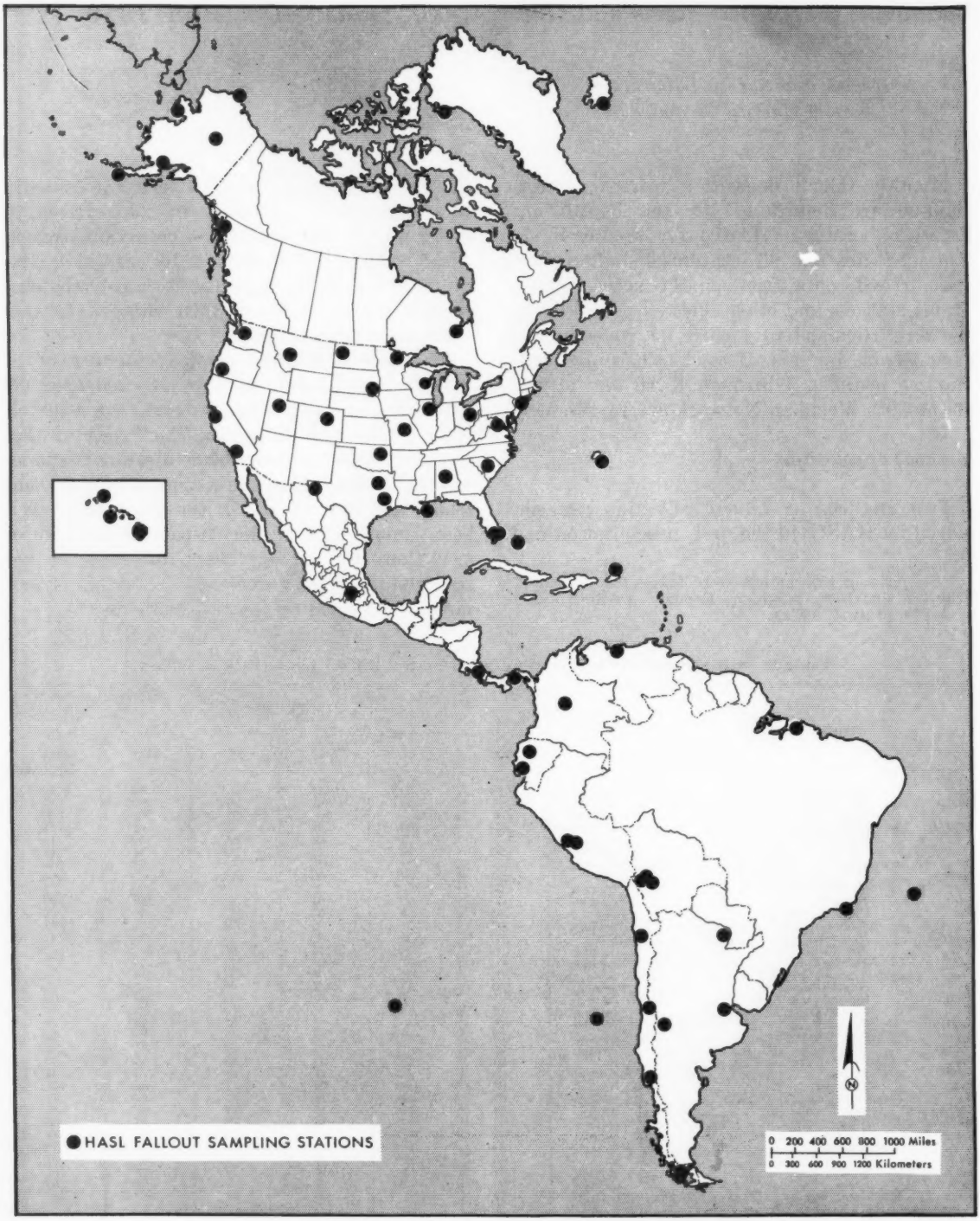

Figure 1. HASL fallout sampling stations in the Western Hemisphere

Table 2. Strontium-90 fallout in the United States, HASL, July–December 1970

Sampling location		Type of collection	Deposition (nCi/m²)					
			July	Aug	Sept	Oct	Nov	Dec
Ala:	Birmingham	pot	0.12	0.13	0.01	0.08	0.08	0.08
Alaska:	Anchorage	column	.18	.06	.06	.02	.01	.02
	Barrow	column	[b]	[b]	[b]	[b]	[b]	[b]
	Cold Bay	column	.14	.08	.08	.06	.04	.05
	Fairbanks	column	.11	[b]	.09	.04	.01	[b]
	Juneau	column	.28	.34	.18	.10	.02	[b]
	Nome	column	.16	[b]	.07	[b]	[b]	[b]
Calif:	W. Los Angeles	pot	.01	[a]	[a]	.01	.05	.07
	San Francisco	column	.01	[a]	[a]	.02	.04	.06
Colo:	Denver	column	.14	.05	.09	.03	.02	[a]
Fla:	Coral Gables	pot	[c].05	[c].05	.06	.06	.01	[b]
	Miami	column	.13	.04	.06	.04	[a]	.01
Hawaii:	Honolulu	pot	[c].13	[c].14	.12	.07	.01	.09
	Lihue	column	[a]	[a]	.04	.03	.03	.03
	Mauna Loa	column	.01	.01	[a]	[a]	[a]	.02
Ill:	Argonne	pot	.18	.44	.06	.06	.04	.03
La:	New Orleans	column	.16	.06	.04	.04	[a]	.04
Minn:	International Falls	column	.14	.31	.06	.06	.02	.02
Mo:	Columbia	column	.10	.16	.07	.07	.04	.06
Mont:	Helena	column	.27	.07	.04	.03	.01	.01
N.Y:	New York City	pot	.13	.12	.06	.09	.12	.05
N. Dak:	Williston	column	.43	.08	.10	.02	[a]	.01
Ohio:	Wooster	pot	.41	.08	.06	.04	.03	.06
Okla:	Tulsa	pot	.08	.09	.12	.10	.01	.05
Oreg:	Medford	column	[a]	.02	.01	.01	.04	.04
S.C:	Columbia	column	.13	.08	.04	.10	.03	[b]
S. Dak:	Vermillion	pot	.29	.07	.10	.08	.05	.03
Tex:	Dallas	column	.05	.11	.02	.38	[a]	.02
	El Paso	column	.06	.01	[a]	.01	[a]	.02
	Houston	column	[b]	.09	.04	.04	.02	[b]
Utah:	Salt Lake City	pot	.15	.06	.12	.05	.07	.10
Va:	Sterling	column	.21	.06	.01	.07	.04	.04
Wash:	Forks	column	.12	.05	.08	.12	.18	.12
Wisc:	Green Bay	column	.22	.14	.07	.06	.04	.01

[a] Zero or trace.
[b] Data not available.
[c] Proportioned from originally consolidated data.

Table 3. Strontium-90 fallout in North and South America, HASL, January–June 1970

Sampling location		Type of collection	Deposition (nCi/m²)					
			Jan	Feb	Mar	Apr	May	June
Argentina:	Buenos Aires	column	0.03	0.10	0.03	0.05	0.05	0.06
	Formosa	column	.10	[a]	.04	.02	.02	.09
	Malargue	column	.02	.07	.03	[a]	[a]	[a]
Bahamas:	Bimini	column	.02	.01	.09	.01	.07	.24
Bermuda:	Kindley AFB	column	[b]	[b]	[b]	[b]	[b]	[b]
Bolivia:	Chacaltaya	column	.02	.01	.01	.01	[a]	[a]
	La Paz (city)	column	.02	.01	.01	[a]	[a]	[a]
	La Paz (Ovejuyo)	column	[a]	[b]	[b]	[b]	[b]	[b]
Brazil:	Belem	column	[b]	[b]	[b]	[a]	[b]	[b]
	Rio de Janeiro	column	.08	.01	.01	.03	.04	.09
	Trindade Island	column	.01	.03	.02	.04	.04	.04
Canada:	Moosonee	column	[a]	[a]	.01	.09	.17	.30
Chile:	Antofagasta	column	[b]	[b]	[b]	[b]	[b]	[b]
	Conception	column	[b]	[a]	.01	.01	.04	.11
	Easter Island	column	.05	.05	.03	.04	[b]	.03
	Puerto Montt	column	[b]	[b]	[b]	[b]	[b]	.11
	Punta Arenas	column	[a]	.02	.01	.02	.02	[b]
	Santiago	pot	[a]	[a]	[b]	[a]	.01	.02
	Santiago	column	.01	[b]	[a]	[a]	.01	.03
Colombia:	Bogota	pot	[b]	[b]	[b]	.01	[a]	[a]
Costa Rica:	Turrialba	column	.02	.02	.04	.17	.07	.04
Equador:	Guayaquil	column	.02	[b]	.01	.01	[a]	[a]
	Quito	column	[b]	[b]	[b]	[b]	[b]	[b]
Greenland:	Thule	column	[a]	[a]	[a]	.01	.01	.03
Iceland:	Keflavik	column	[b]	[b]	[b]	[b]	[b]	[b]
Mexico:	Mexico City	column	[b]	.01	[a]	[b]	.13	[b]
Peru:	Lima	column	[a]	[a]	[a]	[a]	[a]	[a]
Puerto Rico:	San Juan	column	.02	.02	[b]	.10	.19	.24
Venezuela:	Caracas (site 1)	column	.01	[a]	[a]	[a]	.03	.06
	Caracas (site 2)	column	[b]	[b]	.01	[a]	[b]	[a]

[a] Zero or trace.
[b] Data not available.

Table 4. Strontium-90 fallout in North and South America, HASL, July–December 1970

Sampling location		Type of collection	Deposition (nCi/m²)					
			July	Aug	Sept	Oct	Nov	Dec
Argentina:	Buenos Aires	column	0.04	0.04	0.08	0.08	0.05	[b]
	Formosa	column	.05	.06	[a]	.08	.04	[b]
	Malargue	column	.03	.02	[a]	.05	.07	[b]
Bahamas:	Bimini	column	.13	.04	.02	[a]	.02	[b]
Bermuda:	Kindley AFB	column	[b]	[b]	[b]	[b]	[b]	[b]
Bolivia:	Chacaltaya	column	.01	[b]	.04	.04	.03	0.01
	La Paz (city)	column	[a]	[a]	.03	.02	.02	.02
	La Paz (Ovejuyo)	column	[b]	[b]	.01	.01	.01	.01
Brazil:	Belem	column	.05	.03	.06	.02	.03	.02
	Rio de Janeiro	column	.03	.11	.15	.17	.17	[b]
	Trindade Island	column	.04	.06	.06	[b]	.08	[b]
Canada:	Moosonee	column	.18	.20	.14	.02	[b]	.04
Chile:	Antofagasta	column	[b]	[b]	[b]	[b]	.01	[a]
	Conception	column	[a]	.06	.06	[a]	[b]	[b]
	Easter Island	column	.03	.06	.02	.05	.02	.06
	Puerto Montt	column	.15	.10	.11	.10	.06	.14
	Punta Arenas	column	.03	.02	.02	.01	.01	[b]
	Santiago	pot	.05	.05	.06	.04	.01	.01
	Santiago	column	.12	.02	.05	.04	.01	.01
Colombia:	Bogota	pot	[b]	.01	[a]	[a]	[a]	[b]
Costa Rica:	Turrialba	column	.03	.02	.02	[a]	.02	.04
Equador:	Guayaquil	column	[b]	[b]	[b]	[b]	[b]	[b]
	Quito	column	[a]	[a]	[a]	.01	.01	.01
Greenland:	Thule	column	.13	[b]	[b]	[a]	.01	[b]
Iceland:	Keflavik	column	[b]	[b]	[b]	[b]	[b]	[b]
Mexico:	Mexico City	column	.14	.04	.03	[a]	[b]	[b]
Peru:	Lima	column	.02	.04	[a]	[a]	.01	.01
Puerto Rico:	San Juan	column	.08	.07	.05	.04	.03	.03
Venezuela:	Caracas (site 1)	column	.04	.02	.02	[a]	.02	[a]
	Caracas (site 2)	column	.02	[b]	[b]	[b]	[b]	[b]

[a] Zero or trace.
[b] Data not available.

REFERENCE

(*1*) ONG, L. D. Y. Homogeneity between pot and ion exchange column strontium-90 measurements. Fallout Program Quarterly Summary Report, HASL-135: 256-269. Office of Technical Services, Department of Commerce, Washington, D.C. (April 1, 1963)

SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials materials and other media not reported in the previous sections. Included here are such data as those obtained from human bone sampling, Alaskan surveillance, and environmental monitoring around nuclear facilities.

Environmental Levels of Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission (AEC) receives from its contractors semiannual reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational Safety in directives published in the "AEC Manual."[1]

Summary of the environmental radioactivity data follow for the Hanford Atomic Products Operation.

[1] Title 10, Code to Federal Regulations, Part 20, "Standards for Protection Against Radiation" contains essentially the standards published in Chapter 0524 of the AEC Manual.

1. Hanford Atomic Products Operation[2] January–December 1969

Battelle Memorial Institute
Richland, Wash.

A variety of radioactive wastes are generated by the Hanford production reactors, chemical separations plants, and laboratories. High level wastes are concentrated and retained in storage within the project boundaries. Controlled releases of low-level wastes, for which concentration and storage are not feasible, are made to the ground, to the atmosphere, and to the Columbia River. The Atomic Energy Commission (AEC) regulations governing radioactive waste disposal at Hanford are described in the AEC Manual Chapter RL 0510 (*1*). During 1969, the plant facilities were operated for the Atomic Energy Commission by Atlantic Richfield Hanford Company; Pacific Northwest Laboratories of Battelle Memorial Institute; Douglas-United Nuclear, Incorporated; and ITT Federal Support Services, Incorporated.

The Hanford site is in a semiarid region of southeastern Washington State (figure 1) where the average rainfall is about 16 cm (6 inches). This section of the State has a sparse covering of natural vegetation primarily suited for grazing, although large areas near the site have gradually been put under irrigation during the past few years. The plant site covers an area of about 1,300 km^2 (500 square miles). The Columbia River flows through the northern edge of the project and forms part of the eastern boundary. Prevailing winds near the plant production sites are from the northwest, with strong drainage and cross winds causing distorted flow patterns. The meteorology of the region is typical of desert areas with frequent strong inversions occurring at night and breaking during the day to provide unstable and turbulent conditions.

The populated area of primary interest is the tri-cities area (Richland, Pasco, and Kennewick) situated on the Columbia River directly downstream from the plant. Smaller commu-

[2] Summarized from Pacific Northwest Laboratory, "Evaluation of Radiological Conditions in the Vicinity of Hanford for 1969," BNWL—1505 (November 1970).

Figure 1. Hanford project environs

nities in the vicinity are Benton City, West Richland, Mesa, and Othello. The population of the communities near the plant, together with the surrounding agricultural area, is about 100,000.

Sources and levels of environmental radioactivity

Low-level wastes from Hanford operations, fallout from nuclear weapons testing, naturally-occurring radioelements, and cosmic rays contribute to radioactivity in the Hanford environs. Hanford operations that could contribute to radioactivity outside the plant boundary are: (1) the disposal of reactor cooling water to the Columbia River, (2) stack releases at the chemical separations area and laboratory areas, and (3) disposal of radioactive wastes to ground.

The most significant Hanford contributions to off-plant radioactivity and population doses usually originate with reactor cooling water released to the Columbia River. Although airborne releases of iodine-131 have contributed in past years to the thyroid doses of the local population, the major portion of the thyroid doses in recent years has resulted from radioiodines in drinking water.

Noteworthy events during 1969 included the retirement in April of C reactor, the sixth Hanford production reactor to be retired since 1964. Three plutonium production reactors (including the dual-purpose N reactor) remained in operation. Increased atmospheric total beta concentrations observed during June–August were attributed to an announced foreign weapons test in December 1968 (*2*).

Nuclides present in reactor effluent

Cooling of the Hanford production reactors (with the exception of N reactor) is accomplished by a single pass of treated Columbia River water. The N reactor uses recirculating demineralized water as a primary coolant, and all wastewater containing significant amounts of radioactive material is discharged to a ground disposal site near the river. Although some of these radionuclides eventually enter the river, the total quantity of radioactivity entering the Columbia River from N reactor is a negligibly small fraction of that released from the older reactors.

At the older reactors, some elements present in the cooling water are activated during the single pass through the reactors. In addition, radioactive materials formed on the surfaces of fuel elements and process tubes are eventually carried away by the cooling water to the river. Table 1 shows the relative abundance of the radionuclides found in the cooling water of the older production reactors, adjusted to 4 hours after leaving the reactor.

Many of the radionuclides formed in reactor cooling water are short-lived and disappear quickly by radioactive decay. In addition, sedimentation and uptake by aquatic organisms remove some fraction of most radionuclides from the river water. Relatively small amounts of fission products are present in the river because of the fissioning of natural uranium present in the river water, occasional element cladding failures, and fallout from nuclear weapons testing.

Some radionuclides also enter the river from wastes disposed to ground, but their contribution to the total radioactivity was not detectable.

Table 1. Relative abundance of reactor effluent radionuclides [a]

Percent of abundance				
Major (90 percent)	Minor (9 percent)	Trace (1 percent)		
^{24}Na	^{32}P	^{3}H	^{91}Y[b]	^{143}Ce[b]
^{31}Si	^{46}Sc	^{14}C	^{92}Y[b]	^{144}Ce[b]
^{51}Cr	^{69m}Zn	^{35}S	^{95}Nb	^{143}Pr[b]
^{56}Mn	^{72}Ga	^{64}Ga	^{99}Mo	^{144}Pr[b]
^{64}Cu	^{76}As	^{54}Mn	^{103}Ru	^{147}Nd[b]
	^{85}Sr	^{59}Fe	^{106}Ru	^{147}Pm[b]
	^{122}Sb	^{60}Co	^{124}Sb	^{149}Pm[b]
	^{131}I	^{65}Ni	^{131}I	^{151}Pm[b]
	^{140}La[b]	^{65}Zn	^{133}I	^{152}Eu[b]
	^{152m}Eu[b]	^{87m}Sr	^{135}I	^{154}Eu[b]
	^{153}Sm[b]	^{85}Sr	^{136}Cs	^{159}Gd[b]
	^{165}Dy[b]	^{90}Sr	^{137}Cs	^{160}Gd[b]
	^{239}Np	^{91}Sr	^{140}Ba	^{160}Tb[b]
		^{90}Y[b]	^{141}Ce[b]	^{161}Tb[b]
				^{166}Ho[b]
				^{169}Er[b]
				^{171}Er[b]

[a] Trace nuclide composition based on analyses performed in 1964 and 1968.
[b] These radionuclides as a group are denoted hereafter as RE + Y (rare earths + yttrium).

River flow rates

The seasonal fluctuations in flow rate of the Columbia River affect radionuclide concentrations by varying the quantity of water available for dilution of reactor effluent released to the river. In addition, the seasonal scouring of sediments deposited in reservoirs behind each dam causes seasonal fluctuations in transport rates of those longer-lived nuclides associated with the sediments. This is notably true for scandium-46 and zinc-65. Also affected by the flow rate is the time required for a specific volume of water to move from one location to another, which in turn affects the amount of the shorter-lived radionuclides present at any specific location.

The weekly average flow rates of the Columbia River at Priest Rapids and Bonneville Dams are determined from daily average flow rates published by the U.S. Geological Survey (*3*). For 1969, the average flow rate at Priest Rapids was 3,830 m^3/s (135,000 ft^3/s) which was slightly above the 1948–1962 annual average of 3,770 m^3/s (133,000 ft^3/s).

River concentrations

During 1969, samples of river water were collected at Priest Rapids Dam (upstream from the production reactors) and below the reactors at the Richland water plant intake, McNary Dam, and Bonneville Dam. Where possible, cumulative sampling equipment was used to provide a more representative sample than periodic "grab" samples. This cumulative sampling technique, however, prevents calculation of the concentrations of radionuclides with very short half-lives; these were measured in monthly "grab" samples (*4*).

Table 2. Annual average concentrations of several radionuclides in Columbia River, 1966–1969

Radionuclide	Concentration (pCi/liter)							
	1966		1967		1968[a]		1969	
	Richland	Bonneville Dam	Richland	Bonneville Dam	Richland	Bonneville Dam	Richland	Bonneville Dam
Rare earths + yttrium	270	(b)	390	(b)	290	(b)	750	(b)
Hydrogen-3	(b)	(b)	1,500	(b)	1,700	(b)	1,900	(b)
Sodium-24	2,600	(b)	2,600	(b)	2,200	(b)	1,600	(b)
Phosphorus-32	140	23	190	25	92	15	73	14
Scandium-46	30	(b)	60	18	100	20	72	(b)
Chromium-51	3,600	1,300	3,200	1,400	1,500	530	720	240
Manganese-56	290	(b)	520	(b)	250	(b)	1,000	(b)
Copper-64	1,400	(b)	2,000	(b)	1,200	(b)	1,700	(b)
Zinc-65	200	43	220	62	86	<30	72	25
Arsenic-76	420	(b)	400	(b)	320	(b)	310	(b)
Strontium-90	1	(b)	1	(b)	<.6	(b)	<.5	(b)
Zirconium-niobium-95	(b)	(b)	(b)	<5	<6.3	(b)	<3.8	(b)
Technetium-99	(b)	(b)	<5	(b)	<11	(b)	<4.3	(b)
Ruthenium-106	(b)	(b)	(b)	<5	<5	(b)	<4.3	(b)
Antimony-122	(b)	(b)	150	(b)	150	(b)	90	(b)
Iodine-131	18	3	8	3	7.4	<3.2	4.0	(b)
Neptunium-239	770	(b)	1,100	(b)	1,000	(b)	1,100	(b)
Total alpha	<1.3	(b)	<1.2	(b)	[c] <1.3	(b)	<1.0	(b)

[a] During 1968, results for ^{3}H, ^{32}P, ^{46}Sc, ^{51}Cr, ^{65}Zn, ^{95}Zr-Nb, ^{90}Sr, and ^{131}I were based on cumulative samples.
[b] Indicates insufficient data to provide a meaningful annual average.
[c] Based on grab samples (January–June 1968) and on cumulative samples (July–December 1968).

Sampling traverses across the Columbia River at Richland have indicated a slightly nonuniform distribution of the longer-lived radionuclides at this cross section. Entries of the Yakima River just below Richland and of the Snake River just below Pasco influence the distribution of radionuclides in the Columbia below these two points. The magnitude of the influence varies with seasonal changes in the flow rates of the tributaries.

Table 2 shows the annual average radionuclide concentrations in river water at Richland and at Bonneville Dam for 1966–1969. The data for 1966 include the effects of reactor outages during the July–August strike. Comparison of 1969 with 1968 concentrations indicates a general reduction for most radionuclides. The concentrations of several radionuclides, however, increased during 1969; copper-64 concentrations increased slightly, while the rare earths plus yttrium group and maganese-56 showed significant increases. As in past years, total alpha concentrations measured in river water at Richland were near the analytical limit of 1 pCi/liter and were not significantly different from those measured in samples collected upstream from the Hanford plant.

Concentrations of tritium in river water are measured upstream from Hanford at Priest Rapids Dam (where fallout would be the only source of tritium) and downstream from Hanford at Richland. The average concentration of tritium at both Priest Rapids Dam and Richland in 1969 was 1.9 nCi/liter, which was slightly higher than the concentrations measured at these locations during 1968 (1.6 and 1.7 nCi/liter, respectively).

Bonneville Dam, approximately 390 km (240 miles) below the Hanford reactors, is the farthest downstream location where river water is routinely sampled as part of the Hanford environmental surveillance program. Measurements at this location provide a maximum level for the annual transport of specific nuclides into the Pacific Ocean (table 3).

Table 3. Annual average transport rates of selected radionuclides past Bonneville Dam, 1965–1969

Radionuclides	Transport rate (Ci/day)				
	1965	1966	1967	1968	1969
Phosphorus-32	11	9	12	6.2	7.1
Scandium-46	NA	NA	10	7.5	NA
Chromium-51	800	430	610	200	100
Zinc-65	49	21	40	<13	<15

NA, indicates no routine analysis was made.

Transport rates

Figures 2 and 3 show the river transport rates of several radionuclides past Richland. The transport rates at Richland in 1969 for

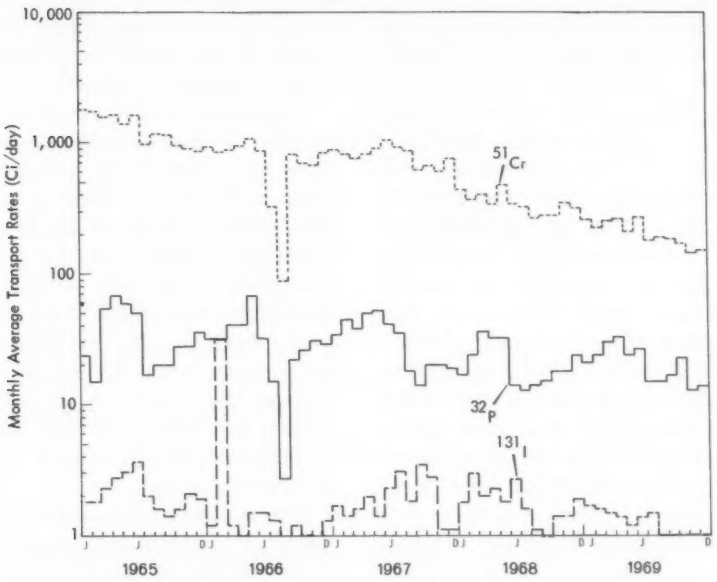

Figure 2. Phosphorus–32, chromium–51, and iodine–131 transport rates in the Columbia River at Richland, 1965–1969

the five radionuclides shown were all lower than the 1968 values, except for phosphorus-32 and zinc-65 which were comparable with the 1968 values. Table 3 shows the annual average transport rates of selected radionuclides past Bonneville Dam.

Trend indicator—whitefish

The Columbia River is popular for sport fishing both above and below the Hanford reservation. Fish feeding downstream from the reactors acquire some reactor-effluent radio-

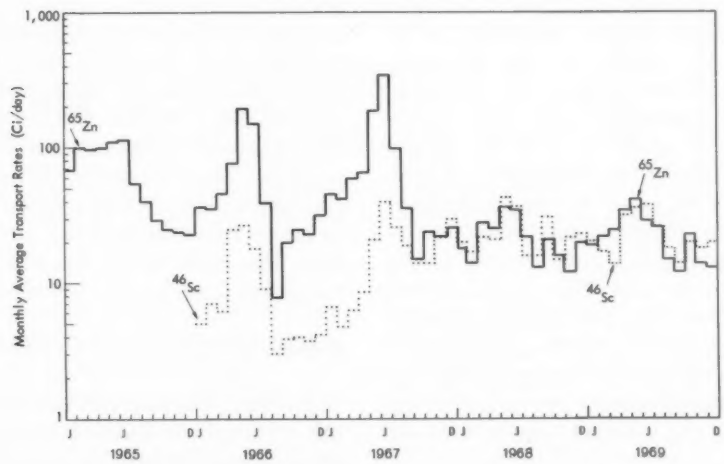

Figure 3. Scandium–46 and zinc–65 transport rates in the Columbia River at Richland, 1965–1969

nuclides, mostly through food chains, with phosphorus-32 being the most significant in regard to population doses. Changes in river concentrations and temperatures may induce changes in concentrations in biological media. However, the ultimate uptake of radionuclides depends on complex environmental interrelationships. Whitefish are the sport fish that usually contain the greatest concentration of radioactive materials. Furthermore, they can be caught during winter months when other sport fish are difficult to sample. Therefore, phosphorus-32 data accumulated from whitefish sampling near the plant boundary are useful as a trend indicator of concentrations in biological media even though whitefish are not the most significant source of radionuclides for the local population.

Concentrations of phosphorus-32 in whitefish during 1969 tended to follow the same seasonal trends observed in past years. But the average phosphorus-32 concentration in fish in 1969 was much lower than expected based upon phosphorus-32 concentrations in the river and river temperatures. The average concentration of phosphorus-32 in whitefish sampled downstream from the reactors during 1969 was 34 pCi/g wet weight as compared with 140 pCi phosphorus-32/g wet weight during 1968 (*5*).

Radioactivity in ground water

Radioactivity in the ground water beneath the Hanford project results primarily from ground disposal of wastes in the chemical separations areas. These wastes are routed to various facilities, dependent upon their radionuclide burden and chemical content. High-level wastes[4] are stored in underground concrete tanks lined with steel. Intermediate-level wastes[5] are sent to underground "cribs" (covered liquid waste disposal sites) from which they percolate into the soil. The areas selected for intermediate-level waste disposal and high-level waste storage have soil with good ion exchange capacity and ground water depths of 50 to 100 m. Low-level wastes[6] are usually sent to depressions in the ground where surface ponds or "swamps" have been formed as the result of the continuous addition of relatively large volumes of water.

One important objective in the management of wastes placed in the ground is the prevention of radiologically important radionuclides from reaching the ground water in quantities that could ultimately cause significant human radiation exposure should they migrate to the Columbia River. An extensive ground water surveillance program is maintained at Hanford to aid in achieving this objective. Hundreds of wells have been drilled at various locations around the Hanford project, including sites within and near crib and tank storage areas, to monitor the movement of radionuclides in the ground water.

The radioactivity in ground water from the chemical separations areas outside the immediate vicinity of the disposal sites is primarily tritium and ruthenium-rhodium-106; cobalt-60 and technetium-99 have also been found but at much lower concentrations. The more radiotoxic nuclides, such as strontium-90, have not been detected in ground water except in the immediate vicinity of a few specific disposal sites.

Figures 4 and 5 show the probable extent of detectable tritium and ruthenium-rhodium-106 in ground water beneath the Hanford project as of December 31, 1969 (*6*). The outer boundaries of the contamination contours, e.g., 0.03 percent of the AEC standard for tritium and 2 percent of the AEC standard for ruthenium-rhodium-106, represent the detection levels routinely achievable for these radionuclides (*1*).

It is possible that some radionuclides from the chemical processing areas are presently entering the Columbia River. However, the concentrations of these nuclides are too small to be routinely measurable in the ground water near the river or in the river itself, and any radiation dose from them is negligible.

Radioactivity in the atmosphere

At Hanford, gaseous wastes from the chemical separations facilities are released to the atmosphere through tall stacks after most of the radioactive material has been removed. Laboratory stacks, reactor-building stacks, and

[4] High-level: >100 μCi/ml.
[5] Intermediate-level: 50 pCi/ml to 100 μCi/ml.
[6] Low-level: <50 pCi/ml.

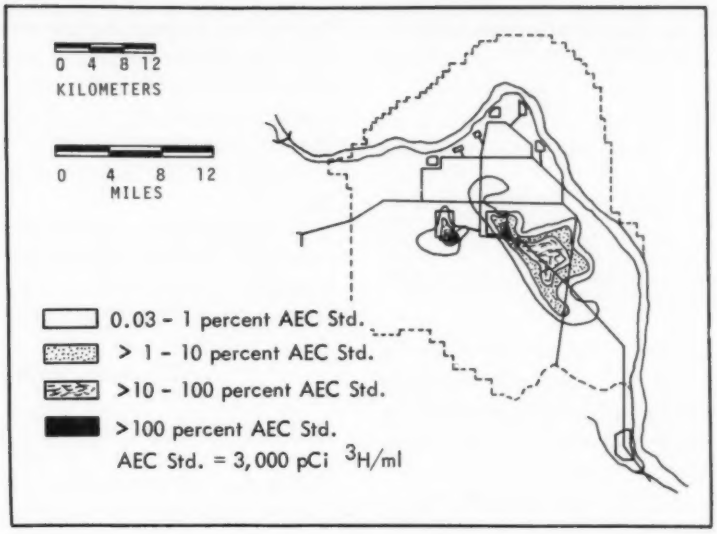

Figure 4. Tritium concentrations in ground water, Hanford, 1969

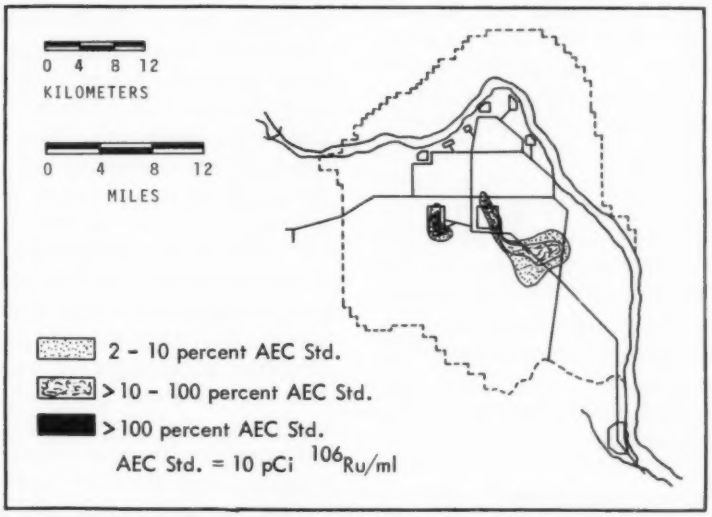

Figure 5. Ruthenium–106 concentrations in ground water, Hanford, 1969

stacks from waste storage facilities release relatively minor amounts of radioactive materials under normal operating conditions.

Measurements of airborne iodine-131, the radionuclide of primary interest, were made (as of the end of 1969) at 25 locations within and near the Hanford reservation. The results of iodine-131 measurements for four selected locations for the past few years, which include contributions from offsite weapons tests, are summarized in table 4. The locations listed in table 4 lie within a 90° sector southeast of the separations areas. The iodine-131 concentrations for 1969 averaged 0.01 pCi/m³ at Richland and Pasco. The annual thyroid dose from inhalation of iodine-131 at 0.01 pCi/m³ for the

Table 4. Annual average iodine-131 concentrations in the atmosphere, 1965–1969

Location	Distance from separation stacks (km)	Iodine-131 [a] (pCi/m³)				
		1965	1966	1967	1968	1969
Ringold [b]	21	(b)	(b)	0.02	0.02	0.02
Benton City	32	0.03	<0.02	.02	<.02	<.02
Richland	32	.02	<.02	.02	.02	<.02
Pasco	51	.03	<.02	.02	.02	<.02

[a] AEC standard—100 pCi/m³ for an individual infant in an uncontrolled area, assuming a 2-gram thyroid and a daily intake of 3,000 liters of air.
[b] Air sampling at Ringold began in January 1967.

2-gram thyroid would be less than 1 mrem,[7] based on appropriate metabolic parameters (*8*) and assuming that the fractional uptake from inhalation is invariant with age.

Continuous sampling for radioactivity associated with airborne particulates was maintained as of the end of 1969 at 34 locations, including those within the Hanford reservation and around the plant perimeter at distances up to 120 km (75 miles). The gross beta activity of each sample filter after exposure was routinely measured (based on strontium-yttrium-90) with detailed radioanalyses performed on filters showing unusual beta activity.

The higher atmospheric concentrations of radioactive particulate material during June–August 1969 compared to the early part of the year were attributed primarily to fallout following a foreign nuclear weapons test in late December 1968. The principal gamma emitters found on filters during June–August were zirconium-niobium-95, cerium-praseodymium-144, and ruthenium-rhodium-106. The concentrations were comparable to those observed during similar events of recent years.

Fallout from nuclear weapons tests

Airborne fallout was detected during most of the spring and summer of 1969. Increases were attributed to the announced foreign nuclear weapons test on December 27, 1969 (*9*). Total beta concentrations in the atmosphere began increasing in March and reached a peak of about 1 pCi/m³ in June and again in late July-early August. Iodine-131 concentrations in the atmosphere remained at or below the analytical limit (0.02 pCi/m³). Slightly increased concentrations of iodine-131 in milk during March (maximum - 8 pCi/liter) were not attributed to this test because of the long time lag.

No significant contribution to atmospheric radiation levels was detected following the announced foreign nuclear weapons tests of September 22 and 29, 1969 (*9*).

Exposure pathways

Radionuclides in drinking water

The city of Richland is the first community downstream (about 75 km) from the Hanford reactors that uses the Columbia River as a source of drinking water. Pasco and Kennewick, a few kilometers farther downstream, also use the Columbia River as a source of drinking water. The Richland and Pasco water plants use a modern flocculation-filtration treatment method; Kennewick water is pumped from Ranney well collectors (infiltration pipes) laid in the riverbank. During 1969, cumulative drinking water samples were collected at the Richland and Pasco water plants, and periodic samples, at all three communities. The Richland and Pasco samples were analyzed for selected individual radionuclides. Detailed analyses of drinking water from these two cities are summarized in table 5. In June, routine sampling at Kennewick was discontinued because of low gross beta radioactivity. Previous experience had shown that concentrations of radionuclides in Kennewick water were significantly lower than at Pasco or Richland.

The concentrations of short-lived radionuclides in the water at the time it is consumed are less than shown in table 5 because there can be a significant transport time between the water plant and most consumers. The transport time may vary from hours to days depending upon the location of the customers on the distribution system and the water demand. In Richland, many residents receive no radioactivity of Hanford origin in drinking water during the times of the year when well water is used to supplement the system supply.

[7] A sustained concentration of iodine-131 at this level in breathing air would imply an annual radiation dose to the thyroid of the standard man (*7*) that would also be less than 1 mrem.

Table 5. Average concentrations [a] of several radionuclides in drinking water, 1969

Radionuclide	Radioactivity concentration (pCi/liter)	
	Richland	Pasco
Rare earths + yttrium	50	24
Sodium-24	1,200	350
Phosphorus-32	35	23
Scandium-46 [b]	24	37
Chromium-51	660	600
Copper-64 [b]	350	69
Zinc-65 [c]	34	30
Arsenic-76	99	38
Antimony-122	56	43
Iodine-131 [c]	3.4	3.3
Iodine-133	[d]20	[e]13
Neptunium-239	450	250
Total beta (counts/min/ml)	2.0	1.2

[a] Measured at the water plants.
[b] January-June average.
[c] Results based on cumulative samples.
[d] Estimate based on an average ratio of $^{133}I/^{131}I$ of 6:1 measured in grab samples.
[e] Estimate based on an average ratio of $^{133}I/^{131}I$ of 4:1 measured in grab samples.

Table 6. Calculated annual doses [a] to selected organs from routine ingestion of drinking water, 1969

Location	Whole body (mrem)	GI tract (mrem)	Bone (mrem)	Thyroid (infant) (0.4 liters/day) (mrem)
Richland [b]	1.8	17	5	24
Pasco	.7	14	3	18

[a] In previous years an intake rate of 1.2 liters/day based on standard man was assumed. The revised intake rate (1.86 liters/day) is used for estimating doses received by the "average" Richland (adult) resident, based on local dietary surveys.
[b] Doses for this station were not adjusted for radioactive decay or dilution in the water distribution system.

Table 6 presents calculated doses to the adult bone, whole body, and GI tract from sustained consumption at an intake rate of 1.86 liters per day,[8] and to the infant 2-gram thyroid from consumption of 0.4 liters per day of drinking water in Richland and Pasco. Annual average concentrations of radionuclides measured at the water plants were used to calculate these doses. The correlation between the GI-tract dose rate at the water plant (established by direct measurement of individual radionuclide concentrations) and the gross beta activity was determined monthly. The correlation used in conjunction with thrice-weekly measurements of gross beta radioactivity at the water plant provided the basis for estimation of the GI-tract dose.

The dose estimates for Pasco residents reflect a downward trend from previous years. The thyroid dose for 1969 from Pasco drinking water (18 mrem) was significantly less than that for 1968 (32 mrem) because of decreased radioiodine concentrations. The average ratio of iodine-133 to iodine-131 of 4:1 for Pasco was based on 1968 measurements on grab samples because the extremely low concentrations of both radionuclides observed in grab samples during 1969 prevented direct measurement of the ratio.

The estimated GI-tract dose to Richland residents from the measured radionuclides in drinking water was somewhat lower in 1969 (17 mrem) than in 1968 (28 mrem). This resulted from the generally decreased concentrations of most measured radionuclides, as well as from the use of well water for over 99 percent of the city water supply in January, when the water filter plant was temporarily shut down. Well water contributed between 4 percent and 61 percent of the total supply in other months. However, radionuclide concentrations measured at the water plant (not adjusted for radioactive decay or dilution in the water distribution system) were used for the dose estimates shown in table 6. The infant thyroid dose during 1969 was about one-half that during 1968 (*5*) because of the decreased concentrations of radioiodines.

Radionuclides in Columbia River fish

The quantities and kinds of fish caught by local fishermen have been previously estimated from surveys carried out from 1961 to 1965 in cooperation with the Washington State Game Department. The maximum estimate of consumption by the fishermen interviewed was 200 meals per year of panfish species (crappie, perch, and bass) taken from the Columbia River. Additional dietary data collected during 1966 and 1967 from household questionnaires and interview surveys also showed individual consumption estimates as high as 200 meals of fish per year.[9] The primary fishing locations

[8] In previous years, an intake rate of 1.2 liters/day based on standard man was assumed. The revised intake rate (1.86 liters/day) is used for estimating doses received by the average Richland adult resident, based on local dietary surveys.

[9] Fisherman survey by J. K. Soldat, Battelle-Northwest, Richland, Wash. (report in preparation).

for the catch of these fish were Burbank, Hover-Finley, and Island View. The average percentage of the maximum annual consumption by species was 73 percent crappie, 16 percent bass, and 11 percent perch. Based on data collected during 1969, the average concentration of phosphorus-32 in such a mixture of panfish was about 12 pCi/g, and that of zinc-65 was 5.5 pCi/g.

From this species distribution and radiochemical analyses of the specimens collected, the "maximum individual's" estimated intakes during 1969 were 0.47 μCi phosphorus-32 and 0.22 μCi zinc-65 (*9*) which are about one-half the corresponding intakes during 1968.

The average consumption of Columbia River fish by Richland residents was estimated from plant employee diet questionnaires (*10*). With the use of the same mixture of species as for the "maximum individual," the "average Richland resident's" intake during 1969 was 0.006 μCi phosphorus-32 and 0.003 μCi zinc-65. These intakes correspond to a bone dose of about 1 mrem or about 0.2 percent of the standard of 500 mrem per year for the population average. For comparison, intakes during 1968 were 0.012 μCi phosphorus-32 and 0.004 μCi zinc-65.

Radionuclides in game birds

Waterfowl and other game birds utilizing the river downstream from the reactors or open low-level waste disposal sites within the plant boundaries may contain phosphorus-32, zinc-65, and other radionuclides as a result of ingestion of insects, algae, vegetation, and water containing these radionuclides, and could be a significant exposure pathway for persons who consume such birds. Some waterfowl remain in this general area throughout the year. The concentrations of radionuclides in game birds at the time of consumption are dependent upon the bird species, the geographical locations of the birds, their current feeding habits, and the elapsed time between killing and consumption of the birds.

For the past 3 years, about 16 km^2 (4,000 acres) of the Hanford reservation situated north of Ringold on the eastern side of the Columbia River have been opened to hunters during hunting season. This area, which is adjacent to the river, was visited in 1969 by 3,050 hunters for an average of about 63 hunters on each of the 48 open days. The U.S. Fish and Wildlife Service has estimated that 3,400 waterfowl, 50 pheasants, 45 quail, and 20 chukar were harvested (*11*). For comparison, the average number of hunters for 1968 was about 33 on each of the 46 open days with a harvest of 1,037 waterfowl, 16 pheasant, 75 quail, and 3 chukar (*12*).

The average concentration of phosphorus-32 in the muscle (the edible portion) of waterfowl collected at the Hanford site for the environmental monitoring program during 1969 was about 72 pCi/g for 46 ducks and 3.6 pCi/g for 12 geese. The maximum concentration in such waterfowl during 1969 was 510 pCi phosphorus-32/g, which is not significantly different from the maximum observed in 1968 for birds collected in the same area.

In addition to the birds collected on the river, nine waterfowl were sampled from swamps and a trench within the plant boundaries. Seven of the samples were collected from swamps receiving low-level liquid wastes near the chemical separations areas. The muscle of these birds contained on the average 34 pCi phosphorus-32/g and less than 1 pCi zinc-65/g. The predominant radionuclide in birds utilizing these swamps, cesium-137, was detected in concentrations ranging from 70 to 420 pCi/g and averaging 300 pCi/g. For comparison, cesium-137 was detected in the muscle of only one waterfowl collected on the river, with a concentration of 1.4 pCi/g, which was considerably below the typical range of concentrations observed in muscle of waterfowl collected from swamps near the chemical separations areas. If an adult had consumed one-half pound of the bird containing the maximum cesium-137 concentration found in muscle from birds collected on the Hanford swamps during 1969, the resulting estimated radiation doses would be 8 mrem for the skeletal bone and 6 mrem for the whole body, about 1 percent of the appropriate standards for individual members of the public.

Near the 100-K reactor area, two waterfowl were collected in late December from a trench

utilized for the temporary retention of reactor cooling water. As expected, the same radionuclides were found in these ducks as were normally found in birds collected on the river. However, because the sources of radioactivity for birds collected from the trench were derived from undiluted reactor cooling water rather than water diluted by the Columbia River, concentrations significantly higher than those in river birds were possible. The predominant radionuclide in the muscle of these two birds, phosphorus-32, was found at 0.003 and 0.110 μCi/g. Immediate consumption of one-half pound of the latter duck (ingestion of a little less than 25 μCi of phosphorus-32) would result in a radiation dose of 4.7 rem to the skeletal bone of a standard man (*13*). However, the consumption of such a bird by any member of the public is considered to be unlikely in view of the fact that very few birds (of over 200,000 in the area) would be likely to spend sufficient time in the trenches near the reactor areas to accumulate such large amounts of radioactive materials. Any delays between the time a bird left a trench and the time of shooting or resulting from the frequent practice of freezing game birds for later consumption would permit radioactive decay and would further reduce the probability of consuming flesh containing the high concentrations of phosphorus-32. For example, in the case we have considered here, a delay of 4 weeks would have reduced the skeletal bone dose to less than 1,500 mrem (the annual standard). As in past years, it is our judgment that ducks collected on swamps, trenches, or ponds are not representative of those available to the general population and that dose estimates derived therefrom are not pertinent for comparison with the established dose standards. Action taken by the reactor-operating contractor to prevent recurrence consisted of screening and partially filling the trenches in the two operating reactor areas. This work to prevent access to the water surfaces was completed in the spring of 1970.

Average concentrations in muscle for upland game birds collected at the Hanford site appear in table 7. The maximum phosphorus-32 concentration in upland game bird muscle was 340 pCi/g in a pheasant sample. For comparison, the maximum phosphorus-32 concentration in similar samples in 1968 was 490 pCi/g in a quail sample.

Table 7. Average phosphorus-32 and zinc-65 concentrations [a] in muscle of river birds, 1969

Species	Concentration (pCi/g)	
	Phosphorus-32	Zinc-65
Duck	72	5.1
Goose	3.6	8.3
Quail	19	2.0
Pheasant	18	2.7
Chukar [b]	5	3.1

[a] Waterfowl collected on the Columbia River and other birds collected within 5 km (3 miles) of the river within the Hanford boundary.
[b] Estimate based on past data and comparison with quail.

Data from a dietary survey of Hanford employees and from a special survey of local hunters and concentration data for the various species have been combined in tables 8 and 9 (*9, 10, 14*). About 30 percent of the game bird meals consumed by local hunters were reported to be birds shot within 5 km (3 miles) of the Columbia River between Ringold and McNary Dam. Past analyses have shown that pheasants collected beyond this distance con-

Table 8. Species distribution of local game birds, 1969

Distribution	Percent					
	Duck	Goose	Quail	Pheasant	Grouse	Dove
River birds [a] of each species	37	32	19	33	8	20
Meals of each species of all bird meals	23	6	12	47	13	No data
River bird meals of each species of all bird meals	8.5	1.8	2.3	16	<1	No data

[a] River birds are defined to be birds shot within 5 km (3 miles) of the Columbia River between Ringold and McNary Dam.

Table 9. Contribution [a] of each species to 100 grams of an average game bird meal, 1969

Species	Weight (grams)	Radionuclide content (pCi)	
		Phosphorus-32	Zinc-65
Duck	23	344	43
Goose	6	4	16
Quail	12	25	5
Pheasant	47	156	42
Grouse	13	3	3
Total	100	530	110

[a] Weighted for location of kill by using measured concentrations for river birds and assuming no phosphorus-32 or zinc-65 in other birds. Also weighted for frozen storage by assuming complete decay of phosphorus-32 but no significant decay of zinc-65 during frozen storage of 44 percent of the birds.

tain little, if any, radioactivity of Hanford origin. About 44 percent of all birds eaten were reported to have been placed in frozen storage, which would permit appreciable decay of any phosphorus-32 before consumption.

The maximum total game bird consumption by adults reported to date is 100 meals per year, which we assume to be about 23 kg/a. Consumption of this weight of the average game bird meal (table 8) would result in intakes of 0.12 μCi phosphorus-32 per year and 0.03 μCi zinc-65 per year, implying 23 mrem to the skeleton of a "standard man" or less than 2 percent of the standard for individual members of the population with bone as the critical organ. Consumption of the estimated annual intake (1.24 kg/a) for the "average Richland resident" (adult) would result in intakes of 0.006 μCi phosphorus-32 and 0.001 μCi zinc-65, implying a total dose of about 1 mrem to the skeleton or less than 1 percent of the appropriate standard (500 mrem/a).

Radionuclides in shellfish

Zinc-65 and phophorus-32 are the only radionuclides in the reactor effluent that are found in sufficient abundance in food organisms beyond the mouth of the Columbia River to be of radiological interest. Oysters have been found to contain higher concentrations of zinc-65 than other common seafoods (*15*). Monthly average concentrations of zinc-65 and phosphorus-32 were periodically measured in oysters grown commercially in the Willapa Bay area. A normal seasonal minimum for phosphorus-32 occurs in the late summer. In 1969, phosphorus-32 average concentrations remained at or below 1 pCi/g from August through December, as in 1968. The annual average concentrations for 1969 were 19 pCi zinc-65/g and 2.8 pCi phosphorus-32/g.

Consumption of oysters containing the 1969 average concentrations at the rate of 50 g/day would result in annual doses of about 4 mrem to the GI tract, 3 mrem to the whole body, and 11 mrem to the bone of a standard man (*13, 16*). Fresh shellfish are not an important item in the average tri-cities diet, but residents of some coastal areas may consume more than the reference value of 50 g/day. For such individuals, shellfish are assumed to be their only source of radionuclides of Hanford origin.

Radionuclides in milk and produce

Irrigation with river water containing reactor effluent radionuclides can influence the radioactivity found in locally grown products. Deposition of airborne materials from Hanford sources and from fallout can be an additional source of radionuclides in these products. Chemical separations facilities are generally the principal local source of airborne radionuclides, although radioactive materials released from ventilation stacks of reactor or laboratory facilities could, under certain conditions, be of interest.

The farming areas closest to the separations facilities is at Ringold about 21 km (13 miles) away. However, much of the land east and south of the project boundary is under cultivation and may be in the path of airborne releases.

Most irrigated farms near the Hanford plant obtain water from the Yakima River, or from the Columbia River above the plant. However, two small irrigated areas using Columbia River water taken downstream from the reactors are the Ringold farms and the Riverview district, west of Pasco. They are 40 and 65 km (25 and 40 miles) respectively, downstream from the operating reactors. The Ringold farms, about 21 km east of the separations areas, involve some 20 people working 2 km^2 (500 acres) of land with fruit as the principal product. The Riverview district comprises about 21 km^2 (5,200 acres) supporting about 1,000 families, the majority of which live on plots of 2,500 m^2 (1 acre) or less and raise family gardens. The principal products from the larger farm plots are hay, fruit, beef, and dairy products. This area is centered, 40 km (25 miles) southeast of the chemical separations plants.

The milk surveillance program maintained during 1969 included samples from local farms and dairies and from commercial supplies available to people in the tri-cities. The concentrations of radionuclides found in milk sold by commercial outlets were similar to those re-

ported by the U.S. Public Health Service and the Washington State Department of Health (*17, 18*). Milk from local farms irrigated with water drawn from the river downstream from the reactors contained phosphorus-32, zinc-65, and iodine-131, as well as fission products of fallout origin. Commercial milk distributed in the tri-cities usually does not contain detectable phosphorus-32 or zinc-65 because only a small fraction of the milk is produced on farms irrigated with water drawn from the Columbia River below the Hanford reactors.

In 1968 and 1969, river-irrigated farms were sampled only in Riverview. Although two farms were sampled during a few months of 1969, the majority of the concentrations of phosphorus-32 and zinc-65 for this Riverview farm were 160 and 110 pCi/liter compared to 310 and 130 pCi/liter, respectively, for the same farm in 1968. Seasonal fluctuations in concentrations of both phophorus-32 and zinc-65, caused primarily by irrigation and feeding practices, followed expected trends.

During 1969, iodine-131 concentrations in both farm milk and commercial milk were generally near or below the analytical limit (3 pCi/liter). The maximum iodine-131 concentration for the period (8 pCi/liter) was measured in a single sample of farm milk collected on March 11, 1969. The average concentration for the year in farm milk was <1.3 pCi iodine-131/liter.

Adult residents consuming milk (1 liter/day) obtained from the Riverview area could have received an annual dose from phosphorus-32 and zinc-65 amounting to about 2 mrem to the GI tract, 1 mrem to the whole body, and 11 mrem to the bone. The same intake of milk by a child with a 2 kg skeleton would result in an estimated bone dose of 39 mrem.[10] The intake of iodine-131 would have resulted in a dose of about 8 mrem to the 2 g thyroid of an infant.

Miscellaneous fresh produce from local farms was sampled periodically for radioanalysis during the 1969 growing season. Results of these measurements were similar to those of previous years and indicated that only small quantities of radionuclides are present in locally-grown produce. Specifically, the concentrations of iodine-131 found in samples of fresh leafy vegetables collected from local farms and markets during May through September were less than or approximately equal to the analytical limit of 0.05 pCi/g.

[10] Based on dose factors of 660 mrem/μCi for ^{32}P and 11 mrem/μCi for ^{65}Zn for the 2 kg skeletal weight.

External radiation

Clusters of three ionization chambers (Victoreen stray radiation chambers) located 1 meter above the ground level on the Hanford reservation and in Richland, measure the gamma radiation exposure from external sources. Data for January 1969 were lost. Data collected during the remainder of the year indicated slightly higher average exposures at both locations as compared to 1968 values. For 1969, the measured exposure averaged about 140 mR/a at Hanford and 110 mR/a at Richland. Essentially all of the exposure at Richland is from natural background and worldwide fallout from nuclear testing.

Estimates of the external radiation dose received from recreational use of the Columbia River in the vicinity of the Hanford project are based on routine measurements at the river shoreline at Richland and Sacajawea Park and below the surface of the river at Richland. The shoreline measurements are made with a large (40 liter) ionization chamber set 1 m back from the water's edge and 1 m above the ground to approximate the dose rates to the gonads of a person on the riverbank. The measured exposure rates include components from radioactivity accumulated in sediment deposits and algal growths at the river's edge as well as from radioactive material in the water. Gamma spectra have shown that scandium-46 and zinc-65 were the major contributors to the shoreline component, and sodium-24 to the water component. Daily and seasonal fluctuations in the river flow rate affect the shoreline radiation levels in several ways including changes in the volume of water diluting the reactor effluent, in the time required for short-lived radionuclides to reach downstream locations, and in the amount of sediment exposed. Other seasonal variations may reflect such things as changes in parent nuclides (such as the spring increase in manganese-56) or in

biological cycles (shoreline insect deposits of debris). For the panfish species consumed in the largest quantities, the primary fishing locations are downstream from Richland. The radiation dose received by fishermen while fishing these locations is estimated from measurements at Sacajawea Park, where the Snake River enters the Columbia.

An avid fisherman (such as the maximum individual), standing on the shoreline at Sacajawea Park for as much as 500 hours during 1969, could have had a gonad exposure to external gamma radiation of Hanford origin of 8.5 mR (about 2 percent of standard for whole body).

The immersion dose received by tri-city swimmers is based on April through October exposure rates at Richland, measured with clusters of five pocket-type ionization chambers positioned about 1 meter below the surface of the Columbia River. Measured immersion exposure rates were primarily due to the gamma emitters (especially sodium-24) introduced into the river with reactor cooling water. In the vicinity of Richland, the average immersion exposure rate during April through October 1969 was 2.7 mR/day. Because the contribution of natural background external radiation during immersion would be quite small relative to the inaccuracies of the measurement, the measured immersion exposure rate is attributed entirely to radioactivity of Hanford origin.

In 1968, teenagers were recognized as the major recreational users of the river. A survey of 430 Richland teenagers indicated an average exposure time of about 115 hours in or along the river for members of this group. About one-third of the time was probably immersion and about two-thirds was shoreline exposure.[11] Using the annual average shoreline exposure rate and the April through October average immersion exposure rate at Richland, the average exposure to the teenage population was estimated to be about 6 mR during 1969. This was somewhat higher than in 1968 because of the slightly increased immersion exposure rate.

The exposures to teenagers who reported considerably greater river exposure time than the average were estimated. The 38 teenagers reporting 300 hours or more per year of Columbia River recreation time were taken to be representative of the critical population group for this exposure pathway. The estimated exposures to external radiation of Hanford origin for individual members of this group ranged from 8 to 53 mR, with an average of about 23 mR. Expressed as whole body dose, this average (23 mrem) for the critical population group with respect to external exposure represents less than 5 percent of the appropriate standard (500 mrem/a) for critical individuals.

The average whole body dose received by the Richland population from recreational use of the Columbia River can be estimated by assuming that other age groups use the river less than teenagers, but with the same proportion of immersion and shoreline exposure times. For the average exposure of the Richland population, an annual Columbia River (recreation) time of 32 hours was assumed. Based on 11 hours of immersion and 21 hours of shoreline exposure in the vicinity of Richland,[12] the whole body dose received by the average Richland resident during 1969 was estimated to be about 2 mrem, or about 1 percent of the appropriate standard of 170 mrem/a.

Fallout from nuclear weapons tests

Dose increments received by residents of the Hanford environs from the fallout nuclides tritium, strontium-90, and cesium-137, have been estimated routinely, although they are not included in the assessment of dose due to Hanford operations. The concentrations of fallout nuclides in the local environs are below the national average because of the low rainfall. Measurements of fallout, like measurements of natural background radiation, help to put the radiation doses resulting from Hanford operations in proper perspective.

Unlike previous years, no increase of iodine-131 concentrations in milk attributable to fallout from weapons testing were observed dur-

[11] Unpublished shoreline data by D. H. Denham, Battelle-Northwest, Richland, Wash. (1969).

[12] Unpublished recreational use data by J. F. Honstead, Battelle-Northwest, Richland, Wash. (1969).

ing 1969, even though foreign weapons tests were conducted in late December 1968 and September 1969 (*9, 19*).

Estimates of tritium intake from drinking water were based on concentrations measured in river water. Concentrations of strontium-90 in locally produced farm and commercial milk are similar to those in commercial milk produced in other areas of low rainfall remote from the Hanford plant (*17*). Strontium-90 in locally produced commercial milk averaged 3.4 pCi/liter during 1969, slightly below that in 1968. Concentrations of cesium-137 averaged below the analytical limit of 30 pCi/liter for both types of milk worldwide. Worldwide fallout is the primary source of strontium-90 and cesium-137 in milk.

Assuming that 40 percent of the total strontium-90 intake from fallout is obtained from milk, the daily intake of strontium-90 during 1969 was estimated to be 12 pCi/day for the "maximum individual" and 4 pCi/day for the "average Richland resident" (adult) (*20*). These values are similar to the intakes estimated for 1968 (10 and 5 pCi/day, respectively). The total intake of cesium-137 during 1969 was about 0.03 μCi for the "maximum individual," and 0.009 μCi for the "average adult Richland resident." These intakes are also similar to those for 1968.

Table 10 shows a summary of the estimated annual dose commitments from fallout nuclides present in the Hanford environs. The strontium-90 intakes are also evaluated in terms of the Federal Radiation Council guides (*7*) for the maximum individual and the average Richland resident. Both correspond to 2 percent of the FRC intake guides for the upper end of Range II.

Table 10. Annual radiation dose from fallout radionuclides,[a] 1969

Radionuclide	Organ	Radiation dose (mrem)	
		"Maximum" individual	"Average" Richland resident
Tritium	Whole body	<1	<1
Strontium-90[b]	Whole body	[b]4	[b]1
	GI tract	<1	<1
	Bone	[b]37	[b]12
Cesium-137	Whole body	[c]2	[c]<1
	GI tract	<1	<1
	Bone	2	<1
Total	Whole body	5	2
	GI tract	<1	<1
	Bone	39	13

[a] Not included in dose summaries presented elsewhere.
[b] The radiation dose commitments shown for bone and whole body represent the dose received over a period of 50 years based on ICRP methods. Only a few percent of the total dose commitment from strontium-90 intake is received during the first year for each of these organs.
[c] For the whole body dose commitment from ingestion of cesium-137 by an adult, the FRC dose conversion factor of 0.06 rem/μCi was used. In previous reports the factor 0.031 rem/μCi based on ICRP values was used. The principal reason for the difference in the two factors is a change in the value for biological half life of cesium-137 from 70 to 100 days in the adult.

Composite estimates of radiation dose

The maximum individual

Experience accumulated from the environmental surveillance program and associated research studies indicates that those individuals receiving the greatest percentage of permissible radiation dose from Hanford sources consume some combination of the following: fish caught locally in the Columbia River, game birds shot near the river, foodstuffs produced on local farms irrigated with Columbia River water drawn from below the reactors, and municipal water with the Columbia River as the source. A hypothetical "maximum" individual has been assigned assumed dietary habits (table 11) which are identical to those used in the 1966, 1967, and 1968 annual reports (*5, 10, 21*).

The consumption rates of most foods for this hypothetical "maximum" individual were compiled from intake rates described in pub-

Table 11. Dietary assumptions, 1969

Foodstuffs	"Maximum" individual	"Average" (adult) Richland resident
Water	730 liter/a	[a]680 liter/a
Milk	380 liter/a	[a]130 liter/a
Meat	80 kg/a	[a]74 kg/a
Chicken	8 kg/a	[a]5.4 kg/a
Eggs	30 kg/a	15 kg/a
Seafood	[d]0	[a,b]1.4 kg/a
Columbia River fish	40 kg/a	[a].48 kg/a
Game birds	[d]0	[a]1.2 kg/a
Leafy vegetables	[c]73 kg/a	36.5 kg/a
Other vegetables and fruits	[c]530 kg/a	200 kg/a
	"Maximum" individual (infant)	"Average" (infant) Richland resident
Water	0.8 liter/day	0.4 liter/day
Milk	1.0 liter/day	.6 liter/day
Leafy vegetables	50 g/day	25 g/day

[a] Based on dietary questionnaires of Richland residents employed at Hanford.
[b] One-tenth of the total is assumed to be Willapa Bay oysters, the remainder free of radionuclides of Hanford origin.
[c] Fresh produce from the Riverview area is assumed to be available only during 5 months of the year.
[d] Insignificant amount and figures in the table are weighted to reflect this fact.

lished dietary surveys and have been documented separately in detail (*22, 23*). The postulated sources include water from the Pasco municipal system and milk, meat, and produce from river-irrigated farms in the Riverview district. The consumption of fish (200 meals per year of panfish taken from the Columbia River) and the total time spent along the river bank to catch these fish (500 hours per year) are based on the values reported in local surveys.

The composite doses estimated for this "maximum" individual are summarized in table 12 and illustrated in figure 6. Decreases were noted for all estimated organ doses with the largest decreases being for the infant thyroid and the adult bone doses.

The estimated bone dose received by the maximum individual in 1969 was 140 mrem (9 percent of the appropriate standard) derived from both radionuclide intake and external radiation. About 66 percent of the bone dose resulted from ingestion of Columbia River fish and about 6 percent from exposure to shoreline radiation while fishing. About 9 percent of the total bone dose was derived from milk, 6 percent from eggs, 4 percent from fruit and vegetables, 3 percent from meat, 3 percent from chicken, and about 3 percent from drinking water. A single radionuclide, phosphorus-32, accounted for 92 percent of the total bone

Table 12. Summary of radiation doses in the Hanford environs,[a] 1968-1969

	1968		1969		Standard (mrem)
	Annual dose (mrem)	Percent of standard	Annual dose (mrem)	Percent of standard	
Maximum individual:					
Bone	250	17	140	9	1,500
Whole-body	24	5	18	4	500
GI tract	62	4	40	3	1,500
Thyroid (infant)	110	7	60	4	1,500
Average Richland resident:					
Bone	13	3	15	3	500
Whole-body	3	2	4	2	170
GI tract	25	5	19	4	500
Thyroid (infant)	39	8	23	5	500

[a] Doses from fallout and natural background not included.

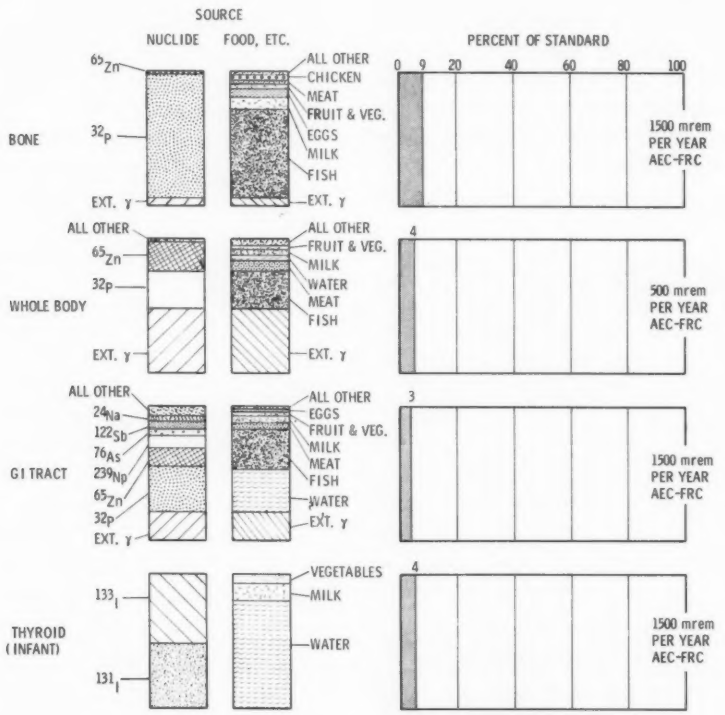

Figure 6. Estimated doses to the "maximum" individual, 1969

dose. For comparison, the 1968 estimated bone dose was 250 mrem (17 percent of standard).

The whole body dose estimate for 1969 for the "maximum" individual was 18 mrem (4 percent of the standard), somewhat lower than the 1968 estimate of 24 mrem (5 percent of the standard). For 1969, about 48 percent of the whole body dose resulted from exposure to shoreline radiation while fishing.

The estimated dose to the GI tract for the maximum individual during 1969 was 40 mrem (3 percent of standard), also lower than the 1968 estimate of 62 mrem (4 percent of standard). In 1969, the principal sources were drinking water, panfish, and external radiation contributing 32 percent, 30 percent, and 21 percent of the total dose, respectively.

The highest radiation doses to human thyroids are those received by infants because of the relatively small thyroid mass (assumed to be 2 grams). For the purpose of estimating thyroid dose for comparison with the standard, the maximum individual is defined as an infant drinking water with radionuclide concentrations equal to those at the Richland water plant and consuming food and milk obtained from commercial sources. Dietary assumptions for 1969 (table 11) were identical to those in 1968 and 1967.

The estimated thyroid dose for such an infant in 1969 was 60 mrem (4 percent of the standard), which is significantly less than the 1968 estimate of 110 mrem (7 percent of the standard). This decrease resulted from a decrease in the measured concentrations of iodine-131 in Richland drinking water in 1969. Measurements of monthly grab samples of drinking water during 1969 indicated the same ratio of concentrations of the short-lived iodine-133 to iodine-131 (6:1) that was observed in 1968. The annual average iodine-133 concentration was estimated by multiplying the annual average iodine-131 concentration in cumulative samples by the average measured iodine-133 to iodine-131 ratio. In 1969, iodine-133 and iodine-131 in drinking water contributed 52 percent and 28 percent of the maximum individual (infant) thyroid dose. Iodine-131 in milk and in leafy vegetables accounted for the remainder.

Table 13 shows the significant decreases in estimated doses to the maximum individual over the years 1965 to 1969, with organ doses adjusted to a comparable basis where necessary to clarify trends. The long-term trend for all organ doses is obviously downward. The bone doses from ingested radionuclides only are shown, because, although exposure to shoreline radiation had been assumed for previous years, no external radiation contribution to the bone dose was evaluated until 1968, when radionuclide intakes were evaluated in terms of mrem rather than expressed as a percentage of the maximum permissible rate of intake (MPRI). The thyroid doses shown are those from intake of iodine-131 only, because iodine-133 contributions were not routinely evaluated until 1967, although iodine-133 was undoubtedly present in drinking water to some extent in previous years.

Table 13. Dose estimates for "maximum" individual 1965 to 1969 [a]

Organ	Percent of standards					Standard (mrem)
	1965	1966	1967	1968	1969	
GI tract [b]	6	5	5	4	3	1,500
Whole-body [b]	8	7	6	5	3	500
Bone	24	22	24	[c]16	[c]8	1,500
Thyroid (infant)	4	6	[d]3	[d]3	[d]2	1,500

[a] Does not include contributions from fallout and natural background radiation.

[b] The annual dose contributions to the whole-body and GI tract from external radiation for the years 1965 through 1969 were estimated to be 15, 13, 11, 9.5, and 8.5 mrem and have been included in the doses listed for these organs.

[c] For comparison, bone doses from ingested radionuclides are shown for all years although in 1968 and 1969, a contribution from external radiation was included in the total bone dose estimates.

[d] For comparison, the thyroid doses listed are from iodine-131 only, although in 1967, 1968, and 1969, a contribution from iodine-133 was included in the thyroid dose estimate.

The "average" Richland resident

Estimates of average consumption rates of several food items were obtained for Richland adults from analysis of dietary questionnaires completed by plant employees. The program and the data have been discussed in another report (*10*). Table 11 includes a summary of the diet for the "average" Richland resident whose food is assumed to come from commercial sources.

In computing doses for the "average" Richland resident, the assumed food sources were

Richland drinking water with average concentrations adjusted for radioactive decay and dilution, Columbia River fish with the average species composition of fish ingested by the "maximum" individual, "average" game birds, and milk, meat, and produce from local stores.

Because no significant contribution from Hanford operations to the background radiation levels in Richland can be discerned, the external dose to the "average" Richland resident is assumed to result only from recreational use of the Columbia River. An estimated dose increment of 2 mrem from immersion in the river and activities along the shoreline was included in the GI tract, whole-body, and bone doses. No such increment was included in the thyroid dose which is calculated for the infant because of the limited use of the river by this age group.

The composite doses estimated for the "average" Richland resident for 1969 (figure 7) are summarized in table 12 with 1968 estimates for comparison. The 1969 doses estimated for the GI tract of the "average" Richland resident and for the thyroid of the "average" Richland infant decreased significantly. No significant differences between 1968 and 1969 dose estimates were noted for the bone and whole body.

The estimated bone dose received by the "average" Richland resident in 1969 was 15 mrem (3 percent of the standard) derived from both radionuclide intake and (as in 1968) external radiation. About 25 percent of the total bone dose was derived from drinking water, 24 percent from meat, 13 percent from external radiation, 13 percent from milk, 8 percent from game birds, 7 percent from panfish, 6 percent from seafood, and 4 percent from remaining food items. A single radionuclide, phosphorus-32, accounted for 85 percent of the total bone dose. For comparison, the 1968 estimated bone dose was 13 mrem (3 percent of the standard).

The whole-body dose estimate for 1969 was

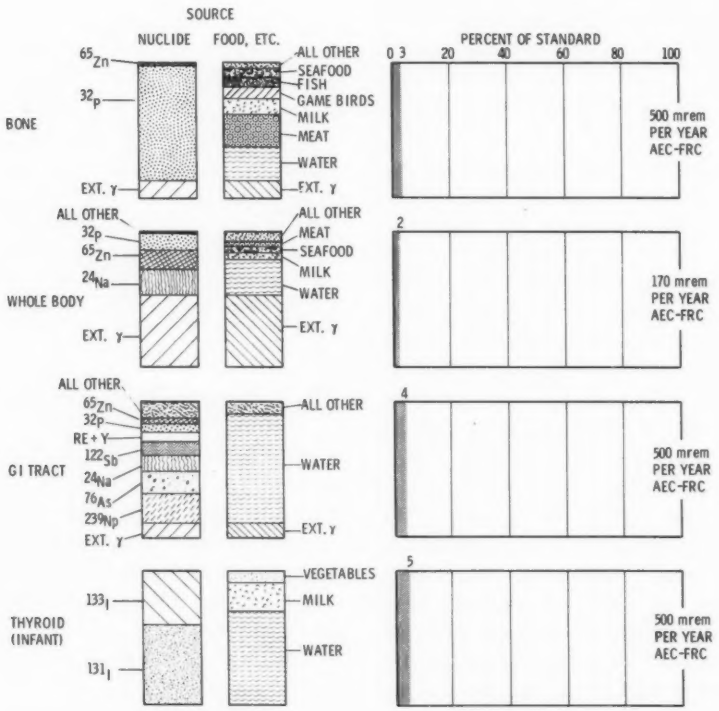

Figure 7. Estimated doses to the "average" Richland resident, 1969

4 mrem (2 percent of the standard), not significantly different from the 1968 estimate of 3 mrem (2 percent of the standard). For 1969, about 53 percent of the whole body dose resulted from recreational use of the Columbia River.

The estimated dose to the GI tract for the "average" Richland resident during 1969 was 19 mrem (4 percent of the standard), somewhat lower than the 1968 estimate of 25 mrem (5 percent of the standard). As in 1968, the principal source was drinking water (81 percent of the total 1969 dose).

The "average" Richland infant is defined as an infant drinking Richland municipal water, with radionuclide concentrations adjusted for radioactive decay and dilution. Dietary assumptions for 1969 were identical to those used in 1968 and 1967.

The estimated thyroid dose for such an infant in 1969 was 23 mrem (5 percent of the standard), significantly less than the 1968 estimate of 39 mrem (8 percent of the standard). This decrease resulted from decreased concentrations of radioiodines in Richland drinking water, which was, as in 1968, the principal source of radioiodines. In 1969, iodine-133 and iodine-131 in drinking water contributed 40 and 30 percent, respectively, of the "average" Richland infant's thyroid dose. Iodine-131 in milk and in leafy vegetables accounted for the remainder.

Conclusions

The Hanford environmental surveillance program for 1969 indicated that most of the environmental radiation dose for the majority of persons living in the Hanford environs was due to natural sources and worldwide fallout rather than to Hanford operations. The major source of low-level wastes released to the environment from Hanford operations continued to be reactor cooling water discharged to the Columbia River. During 1969, radiation doses of Hanford origin were less than one-tenth of the appropriate dose standards and reflected a general decrease from comparable 1968 values for most organs. The gradual shutdown of Hanford facilities has contributed to the decrease in environmental doses over the past few years.

REFERENCE

(1) U.S. ATOMIC ENERGY COMMISSION. Waste disposal, AEC Manual, Chapter RL-0510. U.S. Atomic Energy Commission, Richland Operations Office, Richland, Wash. (July 1967).

(2) BUREAU OF RADIOLOGICAL HEALTH and U.S. ATOMIC ENERGY COMMISSION. Reported nuclear detonations, December 1968. Radiol Health Data Rep 10:45 (January 1969).

(3) U.S. DEPARTMENT OF THE INTERIOR, U.S. GEOLOGICAL SURVEY. Weekly runoff reports —Pacific Northwest water resources (1969), Northwest Water Resources Data Center, Portland, Oreg. (1969).

(4) BATTELLE MEMORIAL INSTITUTE. Evaluation of radiological conditions in the vicinity of Hanford for 1968 (appendices), BNWL-1341 APP. C. B. Wilson, editor, Battelle-Northwest, Richland, Wash. (1970).

(5) BATTELLE MEMORIAL INSTITUTE. Evaluation of radiological conditions in the vicinity of Hanford for 1968, BNWL-1341. C. B. Wilson, editor, Battelle-Northwest, Richland, Wash. (May 1970).

(6) DENHAM, D. H. Radiological status of the groundwater beneath the Hanford project, July-December 1969, BNWL-1233. Battelle-Northwest, Richland, Wash.

(7) FEDERAL RADIATION COUNCIL. Background materials for the development of radiation protetction standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

(8) ROHWER, P. S. and S. V. KAYE. Age-dependent models for estimated internal dose in feasibility evaluations of Plowshare events, Plowshare research and development program report for October 1, 1967 to April 1, 1968, ORNL-TM-2229. Oak Ridge National Laboratory, Oak Ridge, Tenn.

(9) BATTELLE MEMORIAL INSTITUTE. Evaluation of radiological conditions in the vicinity of Hanford for 1969 (appendices), BNWL-1505 APP. C. B. Wilson, editor, Battelle-Northwest, Richland, Wash. (November 1970).

(10) BATTELLE MEMORIAL INSTITUTE. Evaluation of radiological conditions in the vicinity of Hanford for 1967, BNWL-983 and BNWL-983 APP. C. B. Wooldridge, editor, Battelle-Northwest, Richland, Wash. (March 1969).

(11) U.S. FISH AND WILDLIFE SERVICE. Annual Ringold hunting summary, 1969-1970. McNary National Wildlife Refuge, Burbank, Wash.

(12) U.S. FISH AND WILDLIFE SERVICE. Annual Ringold hunting summary, 1968-1969. McNary National Wildlife Refuge, Burbank, Wash.

(13) INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION. Report of ICRP Committee II on permissible dose for internal radiation (1959), with bibliography for biological, mathematical, and physical data. Health Phys 3: 1-380 (1960).

(14) SOLDAT, J. K. Game bird data. Battelle-Northwest, Richland, Wash. (report in preparation).

(15) SEYMOUR, A. H. and G. B. LEWIS. Radionuclides of Columbia River origin in marine organisms, sediments, and water collected from the coastal and off-shore waters of Washington and Oregon, 1961-1963, UWFL-86. University of Washington, Seattle, Wash. (December 10, 1964).

(16) PUBLIC HEALTH SERVICE. National shellfish sanitation program, manual of operations, PHS Publication No. 33. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (1965).

(17) U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE. Radiological Health Data and Reports, Volume 11 (April 1970). Bureau of Radiological Health, Rockville, Md. 20852.

(18) WASHINGTON STATE DEPARTMENT OF HEALTH. Environmental radiation surveillance quarterly data reports, 1969. Office of Air Quality Control, Olympia, Wash.

(19) BUREAU OF RADIOLOGICAL HEALTH and U.S. ATOMIC ENERGY COMMISSION. Reported nuclear detonations, December 1968. Radiol Health Data Rep 10:45 (January 1969).

(20) U.S. ATOMIC ENERGY COMMISSION. Summary of available data on the ^{90}Sr content of foods and of total diets in the United States, HASL-90. Health and Safety Laboratory, AEC, New York, N.Y. (August 1960).

(21) BATTELLE MEMORIAL INSTITUTE. Evaluation of radiological conditions in the vicinity of Hanford for 1966, BNWL-439, BNWL-439 APP. J. K. Soldat and T. H. Essig, editors, Battelle-Northwest, Richland, Wash.

(22) WILSON, R. H. and T. H. ESSIG. Criteria used to estimate radiation dose received by persons living in the vicinity of Hanford: Interim Report, BNWL-706. Battelle-Northwest, Richland, Wash. (July 1968).

(23) ESSIG, T. H. and J. P. CORLEY. Criteria used to estimate radiation doses received by persons living in the vicinity of Hanford: Interim Report No. 2, BNWL-1019. Battelle-Northwest, Richland, Wash. (April 1969).

Republic of France Nuclear Detonations, 1960–1971

Table 1 lists the reported nuclear detonations for the Republic of France from 1960 to 1971. The first nuclear explosions were held in Algeria, and from November 1961 to February 1966, a series of tests was conducted in the Sahara Desert. During 1963 to 1966, France developed a center for testing nuclear weapons in the islands of Tuamotu Archipelago in the South Pacific Ocean (*1*) in the region of the Tropic of Capricorn, approximately 4,000 miles to the east of Australia (*2*).

France did not sign the test ban agreement forbidding nuclear explosions in the atmosphere.

REFERENCE

(*1*) PUBLIC HEALTH SERVICE. French nuclear weapons tests, July-October 1966 and June-July 1967. Radiol Health Data Rep 9:241 (April 1968).

(*2*) GIBBS, W. J., J. R. MORONEY, D. J. STEVENS, and E. W. TITTERTON. Fallout over Australia from nuclear weapons tested by France in Polynesia from July to October 1966. Aust J Sci 29:407-417 (November 1967).

Table 1. Republic of France nuclear detonations, 1960–1971

Date of detonation	Type	Yield	Location
2/13/60	Tower	60–70 kilotons	[a]Reggan, Algeria
4/1/60	Surface	Small	Reggan, Algeria
12/27/60	Tower	Small	Reggan, Algeria
4/25/61	Tower	Small	Reggan, Algeria
11/7/61	Underground	Weak	[b]5.03.07E, 24.03.25N
5/1/62	Underground	Middle	5.02.30E, 24.03.46N
3/18/63	Underground	Weak	5.03.07E, 24.02.28N
3/30/63	Underground	Weak	5.03.25E, 24.02.36N
10/20/63	Underground	Middle	5.02.19E, 24.02.07N
2/14/64	Underground	Weak	5.03.08E, 24.03.13N
6/15/64	Underground	Weak	5.02.04E, 24.03.59N
11/28/64	Underground	Weak	5.02.30E, 24.02.30N
2/27/65	Underground	Middle	5.01.52E, 24.03.31N
5/30/65	Underground	Weak	5.03.03E, 24.03.18N
10/1/65	Underground	Weak	5.02.02E, 24.03.53N
12/1/65	Underground	Weak	5.02.48E, 24.02.37N
2/16/66	Underground	Weak	5.02.28E, 24.02.39N
7/2/66	Barge	Small	Mururoa Island
7/19/66	Air	Small	Mururoa Island
9/11/66	Balloon	Small	Mururoa Island
9/24/66	Barge	Small	Fangataufa Island
10/4/66	Barge	200–300 kilotons	Mururoa Island
6/5/67	Balloon	Small	Mururoa Island
6/27/67	Balloon	Small	Mururoa Island
7/2/67	Balloon	Small	Mururoa Island
7/7/68	Balloon	Small	Mururoa Island
7/15/68	Balloon	0.5 megaton	Mururoa Island
8/3/68	Balloon	Low-intermediate	Mururoa Island
8/24/68	Balloon	Low megaton (First H-bomb)	Fangataufa Island
9/8/68	Balloon	Low megaton	Mururoa Island
5/15/70	Balloon	Low	Mururoa Island
5/22/70	Balloon	Intermediate	Mururoa Island
5/30/70	Balloon	Intermediate (Megaton range)	Fangataufa Island
6/24/70	Balloon	Low	Mururoa Island
7/3/70	Balloon	Intermediate (One megaton)	Mururoa Island
7/27/70	Balloon	Low	Mururoa Island
8/2/70	Balloon	Low-intermediate	Fangataufa Island
8/6/70	Balloon	Intermediate	Mururoa Island
6/5/71	Balloon	Low [c]	Mururoa Island
6/12/71	Balloon	Intermediate [c]	Mururoa Island
7/4/71	Balloon	Low [c]	Mururoa Island
8/8/71	Balloon	Low [c]	Mururoa Island
8/14/71	Balloon	Intermediate [c]	Mururoa Island

[a] First test of a nuclear device, tower was 350 feet high.
[b] Location of tests for which coordinates are given is the Sahara Desert.
[c] Approximate yield; low, 0–100 kilotons, intermediate, 100–1,000 kilotons.

Reported Nuclear Detonations, November 1971

(Includes seismic signals from foreign test areas)

The U.S. Atomic Energy Commission conducted a nuclear detonation of a <5 megaton device (named Cannikin), about 5,875 feet under the surface of Amchitka Island in the Aleutian Chain of Alaska at 11:00 a.m., Bering Sea time (5:00 p.m., EST), Saturday, November 6, 1971. A report from the Palmer Observatory indicated that on detonation, a reading of 7.0 on the Richter scale occurred, as predicted.

No large earthquake was triggered by the detonation, although hundreds of aftershocks much smaller in recorded magnitude than the shock wave from the explosion were registered in the vicinity of the detonation until the cavity created by the detonation collapsed to the surface (this occurred about 38 hours after the test). No aftershocks were observed after cavity collapse. A preliminary survey of the surface subsidence indicated that it had a maximum depth of about 60 feet, with a radius of approximately 2,600 feet. When surface collapse occurred, seismic instruments at Palmer, Alaska, recorded the resulting earth disturbance as having a Richter magnitude (surface wave) of about 5.0.

When Cannikin was detonated, natural ocean wave activity was high in the Amchitka region because of very strong winds the previous day. No tsunami or large ocean wave produced by ocean floor movement was observed or recorded.

The tundra surface in the ground zero area was considerably cracked and otherwise disturbed, as had been expected. Two ponds in the area were drained and three others partially drained. Cliff and turf falls along the Bering Sea for a 2-mile stretch near ground zero were greater than had been predicted, and preliminary indications are that the beach and ocean floor in the near vicinity of the Cannikin site has been lifted permanently by several feet.

Cliff and turf falls along the Pacific Ocean side of the island appeared to be approximately as predicted.

The dike of a pond holding drilling mud, about 4.7 miles from ground zero, developed cracks from Cannikin ground motion, and an estimated 5,000 cubic yards of drilling mud escaped before the cracks were sealed. Most of the mud flowed into a small creek that empties into the Pacific Ocean, with the inflow being at a point about one and a half miles from the ocean. On the basis of other experience, it must be assumed that organisms in the affected portion of the creek were destroyed.

Searches of the seashores of Amchitka located and recovered the bodies of 14 dead sea otters. Two additional injured otters were observed from helicopters, but these animals could not be recovered. Another two abandoned small otter pups were seen but not recovered. Assumption was made that all these died, making a total of 18 (16 on the Pacific side and two on the Bering side).

Twelve of the 14 recovered sea otter bodies underwent autopsies. Deaths of seven appeared to be from overpressure in water, two died from rockfalls, and three apparently were fatally injured by vertical acceleration (upthrust of the ground).

Aerial counts have indicated a lessened number of sea otters in the Bering Sea near the Cannikin site as compared with before the test. The water there is muddied for some distance out because of siltation from turf falls into the water. On the Pacific Ocean side of Amchitka and along other parts of the Bering coast, it appeared that normal numbers of sea otters were observed.

Four dead seals were found in the searches and their autopsies showed that all apparently died from overpressure.

Autopsies of 16 dead birds found on the island indicated that all but one died of the effects of the explosion, seven from overpressure

and eight from vertical acceleration. No eagles or peregrine falcons were among the dead birds. Three or four bald eagle nesting sites along the Bering coast apparently were lost in cliff falls, and two on the Pacific coast. One eagle nesting site on each coast appeared unstable and subject to weather damage. No peregrine falcon nesting sites used in 1971 were lost, but one used in 1969 and 1970 was believed gone.

Hundreds of dead fish were found on beaches, most of them greenling which live around the kelp beds fringing Amchitka. A scuba survey of ocean bottom areas near ground zero on both the Pacific and Bering sides of the island indicated no significant difference in numbers of sea urchins from before the test. Hundreds of dead fresh water fish were found on the borders of small lakes near Cannikin ground zero. Most were sticklebacks (a small trash fish) and a great many of them were in patterns, indicating their kill came from gale winds the day before Cannikin. Some Dolly Varden Char (a game fish) were also found dead.

There has been no detectable release of radioactivity to the marine or surface environment as a result of Cannikin. Measurements will continue for a number of years.

China set off an atmospheric nuclear explosion at approximately 1:00 a.m., EST, November 18, 1971, in the vicinity of Lop Nor. The yield was about 20 kilotons.

A nuclear test in the yield range of less than 20 kilotons was conducted underground on Wednesday, November 24, 1971, by the Atomic Energy Commission at its Nevada Test Site.

The nature of the scientific experiment involved the possibility of a very small release of radioactivity. A seepage of radioactivity did occur about 4 hours after the test was conducted. Aircraft and ground radiation monitoring teams kept track of the radioactivity as it dispersed. A very small amount of radioactivity was detected south of the Nevada Test Site, a few miles east of Lathrop Wells, immediately adjacent to the site. No radiation readings above background have been obtained on the ground off the test site, however, monitoring and environmental sampling are continuing. The level of radiation detected in the air was only slightly above normal background. There is no health hazard either on or off the Nevada Test Site.

Seismic signals, presumably from a Soviet underground nuclear explosion, were recorded by the United States today. The signals originated at approximately 1:00 a.m., EST, November 29, 1971, at the Semipalatinsk nuclear test area and were equivalent to those of an underground nuclear explosion in the intermediate yield range of 20-200 kilotons.

Not all of the nuclear detonations in the United States are announced immediately, therefore, the information in this section may not be complete. A complete list of announced U.S. nuclear detonations may be obtained upon request from the Division of Public Information, U.S. Atomic Energy Commission, Washington, D.C. 20545.

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XUM

SYNOPSES

Synopses of reports, incorporating a list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip them for their files.

IMPACT OF TRITIUM ON THE WATCH INDUSTRY, 1966–1970. *F. J. Bradley, R. Blais and A. Jones. Radiological Health Data and Reports,* Vol. 12, November 1971, pp. 601–610.

Tritium contamination from self-luminous watches at wholesale importers, retailers, and refinishers has been investigated. Air, surface-wipe, and urine samples were analyzed for tritium content by liquid scintillation counting to determine the extent of the contamination.

Eleven storage vaults were surveyed, and the highest human exposure (0.5 rem per year) was found in a firm which handled approximately 200 Ci/a and had poor vault ventilation. Contamination was negligible in vaults at retail establishments.

The casing and repair areas of a firm which handled more than 100 Ci/a had air, surface, and human contamination values of 0.063 pCi/cm^3, 11,200 pCi/100 cm^2, 0.48 μCi/liter, and 0.039 pCi/cm^3, 7,820 pCi/100 cm^2, and 0.22 μCi/liter, respectively, on a yearly average. The casing and repair areas of a firm which handled about 10 Ci/a had air, surface, and human contamination values of background, 430 pCi/100 cm^2, and 0.08 μCi/liter, and background, 807 pCi/100 cm^2, and 0.05 μCi/liter, respectively, on a yearly average.

A refinisher who handled an estimated 30-50 Ci/a had air, surface, and human contamination values of background, 33,600 pCi/100 cm^2 (near stripping solution), and background, respectively, on a yearly average.

KEYWORDS: Dial painting, New York, promethium–147 radium, tritium, watches.

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